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The Bhagirathi-Hooghly Basin

(PROCEEDINGS OF THE INTERDISCIPLINARY SYMPOSIUM)

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FOREWORD

The Bhagirathi-Hooghly has been one of the most important streams of India throughout the ages. It has continued to occupy a pre-eminent position in the field of commerce and industry of this country. It provided the gateway for the entry of European powers into the heart of India and opened up the industrial era for this country. But the river seems to have fallen on evil days during the last half a century. The Port of Calcutta and the Hooghly industrial belt do not now receive all the nourishment they require and so the urban and industrial activities centred round this river are now facing great difficulties. The Hooghly is not only an artery for trade and commerce but is also the life line of supply and distribution for the entire Ganga-Brahmaputra plains.

The crisis which has over taken the Bhagirathi-Hooghly is therefore being viewed with utmost concern by the entire country. It is in the fitness of things that a symposium on this important river was organised by the Department of Geography in collaboration with the premier scientific organisations of the country. This symposium evoked considerable interest and the effort has been rewarded with a rich variety of original papers covering a large number of disciplines. These papers not only portray the condition of the Bhagirathi-Hooghly but also suggest lines along which subsequent studies should be directed. Specialists have not always agreed in their formulations but this is as it should be in academic forums. The views expressed and scientific data marshalled would provide a basis for the planners and the administrators on which they can build and execute their plans.

S. N. SEN

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EDITOR'S NOTE

The Basin of the Bhagirathi-Hooghly may be considered as a function of three variables, erosion, deposition and tectonics. The terrain covered by the Basin, rests on the north-eastern tongue of the Peninsular shield. Some rocks can be traced to those amongst the earliest in India, nay the world over, and the uranium lead ratio would probably suggest an age for them of the order of 2·7 thousand million years. Being of the intrusive variety, such rocks must have been below a cover subsequently removed by processes of denudation. The cover rocks then belong to a still earlier period and the erosive processes operating on the surficial material may reasonably have started 3 thousand million years ago. A part of the Basin, the western part, joining Farakka-Asansol-Banduan may be considered such a region where erosion has been proceeding uninterrupted for this length of time. It has also, over the years, provided materials for sedimentation to constitute the deltaic platform of the Ganga over which the Bhagirathi-Hooghly and its many tributaries flow. Eroded materials derived from the upper reaches of the Ganga and other Himalayan rivers pouring on to the geographical Bengal have also been contributing to the land building process *par se.*

The depositional complex has also been equally effective in the evolution of the Basin. Flood plain deposition together with deltaic sedimentation may be ascribed to two sources, the running water and the tide. The role of either has been well recognised and the interdependance of the two introduces an element of complication the significance of which is still to be fully comprehended. The tectonics provide a third dimension to the whole sequence and orogenic and epeirogenic forces have contributed enormously to the structural character of the platform. The climatic sequence in operation through the geological ages and the landscape cycles affecting the Basin have had no mean contributions for the final output. In other words the physical milieu of the Basin, as seen today, has been the functional outcome of the multiple variables indicated above. But the physical milieu, however powerful, has also been profoundly worked upon by human occupance during the last several centuries. The Bhagirathi-Hooghly Basin provided shelter for the food gatherers as the artefacts discovered in Susunia in the district of Bankura and elsehere in the western part of the Basin testify. The subsistence agriculture which came in its wake and the subsequent commercial farming led to improved techniques of landuse. The settlements, systems of communication and irrigation measures which gradually evolved profoundly altered the natural landscape. The cultural features underwent still more changes as international commerce spread to distant lands. The architectural excavations at Rangamati, then Karna-Suvarna and the Periplus of the Erythrean Sea give impressive evidence of the wide affiliation which the Basin had had in ancient days with far off countries. Ports like Karna Suvarna, Adi Saptagram and Tamralipta flourished till their activities were scotched by riverine decay and political instability. With the advent of the European powers, the landuse took a new turn. Mechanisation and operation of organised capital enabled people to overcome navigational hazards through the Bhagirathi-Hooghly and permitted construction of all-weather roads and railways. Ports, harbours and towns cam to be constructed and the productive organisations took deeper roots. Since the powers that dominated the Bhagirathi-Hooghly Basin did not identify themselves with considerations of welfare for the land as a whole, the cultural features that emerged were not in harmony with the physical, forces constituting the ecological complex ; the developments over the years, ultimately led to overall deteriorations. Rivers are not functioning properly, trade commerce and industries in the Basin are not picking up as they should, settlements are up against overwhelming odds in respect of development and expansion and the public health and hygiene, rural and urban, are assuming menacing propertions.

A new era of renewals and fresh constructions has lately been ushered in by the Government of the country and the international agencies. Although the exact blue print for the Basin in its entirety has not yet emerged, far reaching changes have started taking shape. Planning for utilising the surface and underground water resourcess, restructuring of agriculture, reconstitution of urban and rural settlements into metropolitan districts and growth poles, pressing of public and private capital in the pick-up process, all indicate the magnitude of developmental changes bound to affect the Basin. It is also to be observed that many of the formulations have been on the basis of scanty data. The number of automatic self recording rainguages for the Basin, particularly in its western part are rather scanty. The data for discharge are no better. Micro-contours essential for planning of settlements and communication lines are very much restricted and air survey maps which normally guide soil and vegetation planning are non existent for considerable areas. The information on sub-surface geology provides a sure base for land development projects and the investigations which have been undertaken are also of an indifferent nature. The ground water coverage is also inadequate. Even basic information relating to soils and their carrying capacities are not sufficiently known. Economic data are also inadequate. The input output estimates for most of the fields engaged in production cannot be made correctly, nor projections obtained, since this aspect has been overlooked so long. It was for this that this symposium on Bhagirathi-Hooghly has been convened to focus the attention of the specialists and the public. It has been made interdisciplinary in character to make the study as complete as possible The Symposium could be convened with the untiring effort of the Organising Committee in the composition of which the sponsoring institutions contributed. It has been possible for the Director to publish the proceedings because of the generous assistance to the tune of Rs. 5,000 from the Indian Council of Social Science Research. The shortfall has been made up by the University of Calcutta and the Geographical Society of India. The Organising Committee is particularly thankful to Prof. S. N. Sen, Vice-Chancellor, Calcutta University for his kind patronage, to Prof. P. K. Bose, Pro-Vice-Chancellor (Academic) and Sri H. M. Majumder, ex-Pro-Vice-Chancellor for

Business Affairs & Finance for their active support, to Dr. N. K. Bose, ex-Director, River Research Institute for his kind interest and to the Director-General, Geological Survey of India for allowing the Symposium to be held in the Krishnan Hall of the Survey. I must also convey my thanks to Shri J. P. Naik the Hony. Secretary, Indian Council for Social Science Research for the financial support which his organisation has extended. To each of my colleagues in the Organising Committee I owe a special debt of gratitute. Special mention need however be made of Sri B. Maitra, Dr. S. K. Bhattcharya, Sri S. K. Munsi and Sri M. K. Bandyopadhyay who have scrutinised the texts, Sri Asit K. Sengupta and Sri D. Roychaudhuri, who have redrawn many of the sketches and Dr. R. Bhattacharyya, who has, in addition to the support he has given as a collaborating Editor, taken the enormous pain in seeing the matter through the press. Last but by no means least I am thankful to the R. D. Press who have given all help in the venture.

2. 12. 1972
Calcutta.

K. BAGCHI
Editor.

INTRODUCTION BY THE DIRECTOR OF THE SYMPOSIUM

The portion of West Bengal south of the Padma, together with a good chunk of the Chota Nagpur plateau, over which extends the catchments of the Western tributaries, comprise the hydrological basin of the Bhagirathi-Hooghly. Archaeological finds and traditional accounts ascribe a hoary past for the Bhagirathi-alluvial tract, whereas geomorphologists recognise in the Western crystalline terrain, polycyclic features. A mosaic of diverse typological facets, evolving through varied geological phenomena, has invested the land with a resource complex, the scope and content of which have changed with the times, as reflected in the land-use sequence over the centuries.

Legends have it that even in 2,000 B.C., the Bhagirathi was a flourishing channel carrying the major discharge of the Ganga past Rajmahal. Although in 300 B.C., Megasthenes confirms the appearance of the Padma channel along with the island of the Sandwip, the Bhagirathi still continues to dominate the scene. In A.D. 150, Ptolemy records the flow through the Kambyson mouth (Sagar Island) as the principal channel of the Ganga. The situation upto the days of Rennell continues unaltered. But in subsequent years, the hydrological set up of the deltaic Bengal under consideration has undergone a thorough change much to our confusion.

Precise appraisal of the deltaic processes leading to the development of the spill channels and shifts in the river courses, find mention in a learned paper by Thomas Oldham, in the Proceedings of the Asiatic Society of Bengal, exactly hundred years ago, followed by the findings of Major Hirst and Adams Williams. It was about the time of the first World War that C A. Bentley established the correlation between two seemingly unrelated things—malaria and agriculture in Bengal. This was shortly after the outbreak of the Burdwan fever resulting from a misguided interference of the Damodar flow in the District itself. The significance of the river as an important item of human ecology came to be firmly established. The interest evinced by the University of Calcutta in matters relating to the river and its role in transport and irrigation, goes back to 1920 when Sir William Willcocks was invited to deliver his Readership Lectures, since published by the University, on *Ancient System of Irrigation in Bengal*, in which the speaker elucidated the significance of river alignments in the country and elaborated on the indigenous character of the overflow system of irrigation. *The Changing Face of Bengal* in keeping with hydrological changes was the theme of yet another University publication appearing in 1938, this time by an economist of the reputation of R. K. Mukherjee. This was followed four years later by a penetrating analysis of hydrological problems, also from the University Press, from the pen of S. C. Majumdar, a leading engineer and hydrologist. Soon afterwards came also from the University Press, a geographical treatise on Ganges delta in 1944 from K. Bagchi of the University Department of

Geography in which the deltaic processes and their demographic consequences were elaborated. In the meantime the Second World War had broken out, but shortly before this a comprehensive report on road development in Bengal by King was published from the Bengal Government Press. It provided an elaborate scheme of roads and their classification against a background of ecological surveys giving details of inundation, markets, fairs and melas, trade and commerce and other useful information, all in an integrated manner. It was a superb report.

In 1943 occurred the devastating flood in the Damodar, breaching the five satanic chains in Burdwan and threatening Calcutta itself. This provided the occasion for renewed campaigning on the part of leading scientists like M. N. Saha and B. C. Guha and those associated with them for use of hydrological resources on multipurpose basis. Wavell's decision clinched the issue and Voorduin was invited to draw up a tentative scheme for the Damodar. This opened up a new line of approach subsequently applied to the Mayurakshi and the Kasai. India attained independence and West Bengal appeared in the political scene in a truncated form. The Bhagirathi-Hooghly developed a new significance in our national economy. The River Research Institute with Dr. N. K. Bose as its Director immediately applied itself to the task of evolving solutions for different problems relating to rivers. The hydrological laboratories of the Port Commissioners and Central Government agencies have spurred on their researches. Investigation on ground water potentialities by the Geological Survey of India has added another dimension to the story. A new era of all round hydrological researches have dawned. In 1952 was convened an interesting symposium by the Central Board of Irrigation and Power on the Role of Models in the evolution of hydraulic structures. Its discussion was centred mostly on movements of sediments. Symposia and seminars, on national and international level, have been convened since, on more comprehensive lines. While laboratory investigations are continuing, individual studies are pouring in form different academic institutions. Studies on Bengal Basin by Morgan and McIntire, Biswas, Sengupta, Niyogi, Bose and Basu are some instances selected at random. Even the planners have taken a fancy to our rivers. The team of Dutch experts invited by the former Chief Minister, B.C. Roy has left a report on utilisation of the Sunderban creeks and the C.M.P.O., I.S.I., and related agencies are working on developmental projects. The journals of Geographical Society of India, the Institution of Engineers, the Commissioners for the Port of Calcutta, Indian Association of Geohydrologists, the Regional Science Association, and the annual reports of the River Research Institute provide instances, amongst others as to the varied aspects of planning and development currently engaging the attention of experts. It is interesting to find that a rich crop of young talents has lately been drawn to this field.

It has been in the fitness of things, that the Vice-Chancellor of Calcutta University should sponsor, as president of the Organising Committee, a symposium of this nature. Being an eminent economist he has taken interest in diverse fields. Under his leadership was taken up the first socio-economic survey of Calcutta. He sponsored earlier, an appraisal of the benefits of irrigation on crop production in the Damodar Valley. The department of Geography had taken a leading part in organising a diagnostic survey of the Damodar Valley region under the guidance of Dr. S. P. Chatterjee and his colleagues at the instance of the Ministry of Irrigation and Power on request from the Planning Commission. The response to Vice-Chancellor's invitation has been spontaneous. The Geographical Society of India, the Indian Association of Geohydrologists, the Indian Statistical Institute, the Regional Science Association (India) the Commissioners for the Port of Calcutta, the Institution of Engineers (India) and the River Research Institute, West Bengal, have come forward with their generous collaboration. About 50 papers have been received which will be discussed in 5 technical sessions according to the programme circulated. The problems of the basin are many. These relate to hydrometeorology, trade and commerce, urbanisation and industrialisation, transport and navigation, sanitation and water supply. But I shall not anticipate these. They will emerge in course of discussion. It has been very kind of Dr. N. K. Bose, Ph.D., F.N.A., ex-director of the River Research Institute and a leading hydrologist to have agreed to inaugurate the symposium. I would request him for inauguration.

Dated, Calcutta
the 19th May, 1970

KANANGOPAL BAGCHI
Director of the Symposium.

THE BHAGIRATHI-HOOGHLY—A FEW REMARKS

Dr. N. K. Bose

Our attention will be focussed on some important problems relating to Bhagirathi-Hooghly Basin. The *laws of nature*, are inexorable and inspite of the heat and controversy raging round us, the will ultimately prevail Let us, therefore, concentrate our attention to some of these problems that might affect our dear land and the City of Calcutta and not be disturbed by what is happening outside the four walls of this hall. Some of these problems are so acute that we must rise over our parochial outlook and face them boldly from a scientific and practical point of view.

Beyond the outfall of the Kosi, the river Ganga turns into the plains of Bengal round the outcrops of the Rajmahal hills receiving only a few local drainage channels on the left bank. A few kilometers below Farakka the river starts throwing off distributaries that join the right-hand channel Bhagirathi (Ganga) which formed once the main arm of the Ganga. Through this channel used to flow all the low water discharges of the river into the Bay of Bengal, whereas during the flood stages, the overflow used to take place through the left arm of the Padma (Ganga) which after throwing off distributaries like Jalangi, Mathabhanga-Ichhamati-Bhairab, Nabaganga and Gorai, is joined by the Brahmaputra and later on meets the Bay of Bengal as the Meghna. The delta between the two arms Bhagirathi-Hooghly and Padma-Meghna is well known as the delta of the Ganga from very early days. The area covers roughly 58,752 sq. km. i.e. a little over one-fourth of Bengal (undivided). On its right arm can be seen the ruins of a number of very ancient localities once prosperous and famous centres of culture, art and industries. The cities of Gaur, Murshidabad and Berhampore—the centres of activities of Muslim Satraps of Bengal, Katwa and Nabadwip—the cities of ancient Hindu cultural revivals, and latest though not the last, the industrial complex stretching for kilometers on both banks of the river Bhagirathi-Hooghly, the metropolitan city of Calcutta. All this array of ancient and modern centres of art, culture and industries indicates that the right arm of the delta was the main channel of the river Ganga before the left arm Padma-Meghna started drawing more and more discharges towards the end of the 18th century. As the left arm improved, the right arm deteriorated rapidly. Towards the end of the 19th century, and in the early twenties, when Calcutta had developed into a centre of trade and commerce for the whole of Eastern and North-Eastern India with the hinterland of Nepal, Bhutan, Sikkim, and Tibet, the river Hooghly showed signs of deterioration that appeared to be fatal for the development of the City and the Port of Calcutta. Extensive dredging of the river channel was resorted to by the Port Commissioners of Calcutta that appeared to be successful in the early days but with the rapid deterioration of the navigability of the channel, it was quite apparent that other methods besides dredging had to be resorted to, if the Port and City of Calcutta were to be kept functioning satisfactorily. A number of experts were consulted and commissions were constituted to study the problem and suggest remedial measures. The main factors that were considered to be responsible for the rapid deterioration of the navigability of the river are :

1) The duration and intensity of upland supply from the main stream Ganga into the Bhagirathi channel was limited to the months of mid-June to mid-November and the volume of supply diminished from about 75 to 80 thousand cusecs to nil.
2) As against this the arm Bhagirathi-Hooghly receives a strong tidal inflow from the Bay of Bengal throughout the year.

Besides these two main factors there are other natural phenomena that have aggravated the situation. A close study of the navigational difficulties of the Hooghly channel between the Port of Calcutta and the sea-face has revealed the unpredictable nature of the sand-bar movements that constitute the hazardous nature of navigation in some reaches of the river between the Port and the sea-face. You will hear more of this from other speakers who have made a special study of the problem. I shall try to explain to you why this is so and what steps have been advised in the Ganga Barrage Project to overcome these difficulties.

The Bhagirathi takes its water supply from the river Ganga as the latter starts rising with the advent of the monsoon season. Its main offtake point at present is at Biswanathpur, a village upstream of Jangipur (Berhampore). At this point, it receives its first tributary from the right bank, Bansloi-Pagla, the contribution from this tributary is small and when the main channel, Bhagirathi, is in spate, there is a reverse flow into the bil area in the hinterland. Further downstream the following tributaries flow into the river Bhagirathi, Dwarka, Brahmani, Mor and Kopai. All these tributaries flow into a bil area known as Hijol bil and in consequence their contribution to the Bhagirathi flow is small and very often negative. These, therefore, do not pose any serious problem so far as the Bhagirathi is concerned.

The next tributary is Ajay that joins the Bhagirathi at Katwa. It is this tributary that poses the biggest problem for control of the river Bhagirathi-Hooghly specially in the navigation practices beyond the Port of Calcutta. The Ajay is a mighty stream gathering all the runoffs from the Santhal Parganas, where the terrain is hilly, rainfall is copious but spasmodic and the river flow is torrential or negligible. The total catchment area is 6,760 sq km out of which less than 50 per cent is hilly and the rest flat plains in West Bengal. During the rainy season, the river channel is either in spate or runs in trickle, varying from 300,000 cusecs to about 1000 cusecs. This extremely flashy tributary of the Bhagirathi creates havoc as it debouches into the main stream at Katwa where the capacity of the latter is only about 127,000 cusecs. Such floods occurred on a number of occasions previously. Records available with the West Bengal Government indicate that they took place in 1905, 1916, 1917, 1922, 1931, 1933, 1939, 1943, 1948, 1949, 1956 and 1959.

A description of the 1956 flood as recorded in the report on the floods of

September-October 1956 in Central, Western and Southern districts of West Bengal is reproduced as follows :

"This abnormally heavy precipitation (13.4″ in 3 days) caused a flood of the magnitude of 300,000 cusecs down Satkahania. As this volume of water came into the Bhagirathi at Katwa, though the Bhagirathi level was 6.5 ft. below the danger level at the time, the river channel could not accommodate this heavy discharge and the river level was backed up to Berhampore a distance of 48 miles. The flood wave went down into the Bhagirathi beyond Nabadwip town into the Hooghly locking the outfalls of Banka, Kheri and Brahmani channels and all drainage channels."

Though the 1956 flood in the Ajay was an abnormal one, floods of similar magnitude had occurred on many occasions as stated before and flood waves accompanied by spasmodic bed movements must have followed these flood waters right into the navigation channel of the Hooghly beyond the Port of Calcutta. It generally takes 2 or 3 weeks for such disturbances at Katwa to reach the sand bars in the navigational channel of the Hooghly. The period and the nature of disturbances depend on the intensity and frequency of such freshets brought into the Bhagirathi at Katwa by the river Ajay. It has therefore been proposed in the Project for the preservation of the Port of Calcutta that steps should be taken to control Ajay floods for successful operation of the Project.

I would therefore suggest that the authorities organising this symposium on the Bhagirathi-Hooghly basin to press upon the Government of India to take up the construction of a flood-control reservoir on the Ajay on a priority basis so that the authorities operating the Ganga Barrage Project may not be handicapped due to the lack of any control of Ajay floods.

It is expected that with the proper operation of the project for the preservation of the Port of Calcutta as outlined by the authors of the Project improvements in the navigational facilities in the Hooghly will be gradually attained. But this is expected to be effective upto a point beyond which suitable training works and occasional dredging will be required in the transition period.

I shall not take more of your time by discussing the operational details of the Project. These will be developed as more experience is gained. But I would like to present to you another picture of the basin which will affect the Hooghly adversely.

Besides Bhagirathi-Hooghly and the Ajay, another system of rivers, comprising Damodar-Rupnarayan, drain the south-western part of West Bengal. Of these, Rupnarayan is a vast tidal basin that receives the tidal inflow at Geonkhali. This influx of tidal waters enters the estuary between the Saugor island and the eastern coast of the Midnapore district of West Bengal. This tidal influx is governed by the tidal energy present in the head Bay of Bengal and though it varies from season to season, it cannot be usually affected by any alteration in the configuration of the river channel higher up. The total tidal influx after it passes Diamond Harbour divides into two branches one of which enters the Hooghly channel at Hooghly point, another enters the Rupnarayan basin.

The Rupnarayan basin plays a duel role equally important and vital.

1) It receives a part of the tidal impulse that enters the Hooghly estuary from the head Bay of Bengal and acts as a spill area, reducing the tidal flow that would have otherwise gone up the Hooghly channel, counteracting the flushing action of freshet discharges from the Ajay and the Bhagirathi rivers.
2) It receives the flood waters of rivers Damodar, through Mundeswari channel, and Darakeswar and helps to reduce the flood menace in the lower and trans-Damodar area.
3) It receives the drainage waters from a vast area from about 500,000 acres in the district of Burdwan, Bankura, (trans-Damodar area), Howrah and Midnapore from both its banks.

It will therefore be seen that the Rupnarayan basin plays a very vital role in the economy of the State of West Bengal, south of the river Ganga.

Let us see what will happen if the capacity of the Rupnarayan basin is reduced. We will see later on how this can take place and to what extent this has already taken place.

The ultimate effect of the reduction of the capacity of the basin will be to restrict at Geonkhali the inflow of tidal waters into the Rupnarayan from the Hooghly estuary.

As the reduction takes place, gradually the share of tidal influx into the Hooghly channel beyond Hooghly Point will also increase. This will be accompanied by a rise in the range and upward thrust of the Hooghly tides. Ultimately the tidal limit of the Hooghly channel will go higher and higher up. The silt and sand brought down by the Bhagirathi and Hooghly during the freshet season instead of being gradually pushed down to the sea face by successive freshets will be retarded in their downward course and heaved up to the apex of the tidal basin between Kalna and Nabadwip. Thus the navigability of the river Hooghly between the Port of Calcutta and the sea will be adversely affected and the salinity of the river water will increase.

Let us now see what has happend to the tidal basin of Rupnarayan during the last 30 years between 1938 to '68. This period is significant, as during the first 20 years 1938 to '58, there was no appreciable human interference with the natural flow of water into the basin excepting the construction of short lengths of embankments in the lower reach of the basin. During the last 10 years, 1958 to '68, D.V.C. dams came into operation controlling flood discharges coming down through the Mundeswari channel (outfall of the Damoder into the Rupnarayan basin). During these 30 years 1938 to '68 cross-sectional surveys below 10 K.O.D.S. of the basin were taken by the Commissioners for the Port of Calcutta from Geonkhali to Kolaghat (immediately upstream of the South-Eastern Railway bridge over Rupnarayan). The cumulative sums of sectional areas in 10^3 sq. ft. below 10 K.O.D.S. are noted in the table I for 1938, 1944, 1953, and 1962. (There are 45 cross sections in this reach, cross section 1 corresponds to Geonkhali, cross section 45 corresponds to Kolaghat).

TABLE—1

No. of cross sections.	1938	1944	1953	1962	Percentage reduction in 1962 with respect to the average cubature volume in 1938, 1944 & 1953
45— 1	2675.909	2563.305	2061.322	2260.367	13.51
45—36	221.973	227.462	248,428	139.114	+ 40.20
35—26	357.382	274.018	337.968	241.918	23 55
25—16	527.994	501 655	521.259	440.931	14.71
Pyratungi					
15— 6	928 785	834.638	878.553	816 791	7 25
5— 1	659.774	725.532	615.114	621.613	6.78

It will be seen that the cubature volumes of the Rupnarayan basin have remained more or less steady in the surveys upto 1953, but there are certain reductions in the cubature volumes specially in the upper reach in 1962 survey.

Since the construction of the DVC dams in 1958 when the moderation of flow for flood control was undertaken, both the frequency and duration of high flood discharges coming down the Mundeswari channel (present outfall of the Damodar into the Rupnarayan flood basin) have been reduced.

TABLE—2

Discharge values in cusecs	Pre-dam period 1946-57		Post-dam period 1958-63	
	No. of occasions.	Duration in hrs (annual average)	No. of occasions.	Duration in hrs (annual average)
75,000	120	217·7	53	190·3
100.000	53	97 8	26	95 3
150,000	28	37·1	5	18·3
200,000	11	15·8	1	6·3
250,000	6	7 8	1	4·7
300,000	4	2 4	1	1·3

Table 2 gives an idea of the frequency and duration of daily observed discharges at Rondia below the dams in the pre-dam and post-dam period.

It will be evident from table 2 that the reductions in frequency and duration of floods of higher magnitude, specially above 150,000 cusecs have been very marked after 1958 when the DVC dams came into operation.

Comparing these two tables it will be seen that the deterioration after the DVC dams came into operation is more marked in the upper reaches from Kolaghat to Pyratungi (which is located near the middle of the reach between Geonkaali and Kolaghat) than in the lower reach. Further the bed slope of the reach in the upper portion is almost flat while that in the lower reach downstream of Pyratungi to Geonkhali is fairly steep, being of the order of 7 ft. per mile. This point is further clarified by the curve showing the average bed levels of the river Rupnarayan from Geonkhali upwards observed during spring tide July 20, 1966 (in G.T.S. datum) through Pyratungi, Dainan, Kolaghat, Bakshi khal (immediately below Mundeswari-Damodar outfall) and to Bandar, the northernmost point of the basin where Darakeswar joins it.

This picture is very instructive. It shows that from Geonkhali to Pyratungi (19.2 kilometre) the above bed level is below O/G.T.S. indicating that the tidal action is very active. Between Pyratungi to Dainan it is uniformly high, the sands brought up by the tides are heaved up here as the freshet discharge is feeble, between Dainan and Kolaghat there is a deep scour hole evidently caused by the railway bridge piers, between Kolaghat and Bakshi khal outfall (49.6 km.) the average river bed has gone up very high, evidently caused by the constricted railway bridge piers. Upstream of Bakshi khal outfall, the flood waters of the lower Damodar and trans-Damodar area have not been able to keep the basin bed level below O/G.T.S.

A detailed analysis of the cross section show that the capacity of the Rupnarayan basin (12 K.O.D.S.) has decreased by one per cent per year between 1955 to 1962 and by 2 per cent per year between 1962 and 1965.

Summing up we may say that the rises in the bed level of the Rupnarayan tidal basin that have been very pronounced and progressively increasing since 1958, the year DVC flood control operations came into action will

(1) affect adversely the navigability and salinity of the river Hooghly upstream of the Hooghly point as this will force more of the tidal afflux through the Hooghly channel.

(2) head up the flood waters of the Lower Damodar and Dwarakeswar spreading them over the trans-Damodar and Arambagh area delaying their early evacuation.

(3) retard the drainage of the Daspur area measuring about 312 sq. km. This area is enclosed by Rupnarayan, Silabati, Palaspai and Durbachati khal and is subject to flooding every year when high tides in Rupnarayan coincide with heavy rainfall.

Before I close I would like to point out that of late there have been proposals to construct one or two more dams in the river Damodar and its tributaries to add to the water potential and flood control capacity of the D.V.C. Inspite of vehement protest from West Bengal Officers, the Tenughat Dam was sanctioned and works started to supply waters to Bokharo Steel Plant. During discussions for the sanction of the construction of this dam on the Damodar upstream of Ayyar Site, it was agreed by the Committee presided over by the Union Minister, Dr. K. L. Rao, that to compensate for the additional withdrawal of water from the Damodar system by the Tenughat Dam, a dam should be constructed on the river Ajay in Bihar and sufficient water should be diverted to the Maithon Dam through a channel connecting the two dams. In clear violation of this agreement nothing has been done so far about this. Proposals on the other hand are now being freely mooted that another dam be constructed in the D.V.C. area to augment the water potentials and flood control capacity of the project further. It is therefore high time that the public be informed about the effects that have already taken place due to the four existing dams viz. Maithon, Panchet, Tilaiya and Konar. These four dams have been in operation since 1958 and they have controlled a number of floods—big and small during this decade 1958-'69. Effects of such control on the capacity of the Rupnarayan tidal basin and on the low water drainage capacity of the lower Damodar (Mundeswari), Darakeswar, Silai, Kosai and other drainage channels should be carefully studied before any further step is taken to increase the flood control capacity of the project.

There are a few sizeable dam sites on the upper Ajay, one of which falls in West Bengal in the vicinity of Chittaranjan. The capacity of a dam about 30 meters. high here will accommodate the same volume of water as the Maithon Dam of DVC. Further there is a narrow strip of high land between the frings of this reservoir and that of the Maithon. With the help of a connecting channel whose length will be barely two miles, the excess water from the Ajay may thus be diverted to the Damodar system thus compensating for the reduction of the flushing water in the latter system due to the hold up in the Tenughat Reservoir.

The organisers of this symposium may consider this suggestion and press upon the Govt. of India to take up the matter along with the Ganga Barrage Project. The presence of a flood moderating reservoir on the Ajay will make the operation of the Ganga Barrage Project much easier and its success assured.

THE BHAGIRATHI-HOOGHLY BASIN

Prof. S. P. Chatterjee

I had been to Stresa short while ago for participating in the Fifth Conference of the International Cartographic Association. I mention this to you as I had the pleasure to see there a number of hydrological maps of several river basins of Japan in the map exhibition arranged in the Congress Palace there. These maps depicted the flood-affected areas in the river basins, showing precisely the nature and extent of damages caused by successive floods within a certain period, the changes in the micro-relief of flood-affected areas as a result of erosion and deposition by flood waters, lengths of the period of stagnation, depths of stagnant water, directions of flood currents and many other features. These maps help the authorities in assessing flood damages. In this connexion I would refer you to the Report by Masahiko Oya on *Determination of the nature and extent of flood damage downstream from Pamong in the Mekong River Basin.* It is an ECAFE publication. The Japanese geographers also exhibited large-scale geomorphological maps which helped them in utilising fully every bit of their land either for farming or for horticulture depending on its micro-relief. Land was divided broadly into two slope categories—stable slopes on firm mountainous land and unstable slopes caused by agents of erosion. The former was then divided into 3 types—ridge, valley and mixed at different gradients, carefully marked on the map. On the areas shown as unstable slopes micro surface features such as watersheds, ridges, cliffs, scarps, rock collapses, bare rocks without a soil covering caused by recent fracturing and sliding as a result of minor earthquakes, larger land slides, progressing or halted. I wish that we could prepare some such maps of our river basins on the lines that the Japanese are doing in their country. Now I pass on to the subject matter of our Symposium.

India, a large tropical country, covering some 3 million sq. km has been subjected to fluvial erosion very extensively since the establishment of the monsoon regime as a direct consequence of the upheaval of the Himalaya in the north in the beginning of Tertiary age. This has subsequently resulted in carving out a number of basins in North India by flowing surface water which provide ample opportunities for a rapid growth of human settlements in the basins and posed, as time passed on, many problems especially wherever these basins were overcrowded and their natural drainage channels were interfered with by man rather prematurely for his immediate benefit. The Bhagirathi-Hooghly is one such river basin perhaps the only one of its kind, that poses so many problems directly to its 15 million inhabitants because of the progressively silting up of the Bhagirathi reach of the river and decrease of water even in the tidal Hooghly reach, and indirectly to the much larger section of the people living outside the basins because of their dependence on the basin within which is located the port of Calcutta with its annual turnover of 7.5 million tonnes. It is, therefore, in the fitness of things that we should organise from time to time, discussions on the various aspects of the problem—fluvial morphology, hydrological character, delta formation and coastal processes, navigation and planning for the development. The National Atlas Organisation, Government of India has also been working on this problem for sometime past and brought out a number of maps showing the detailed land forms of the Basin, its land use, distribution of population and transport network. The Calcutta Metropolitan Planning Organisation is also vitally interested and brought out a report on the basic development plan of the Calcutta Metropolitan District 1966-86.

The problems in the Bhagirathi-Hooghly basin which occupies a part of still wider structural basin in Bengal are not a new one, although their seriousness has never been felt as acutely as in the present time, more so since the partition of our State in accordance with the Radcliffe Award in 1947. The future of the City of Calcutta, the greatest metropolis, port and commercial-cum-industrial complex of India is linked up with this great river, which used to receive in the past the bulk of the waters of the Ganga before its diversion eastwards through the Padma channel in the seventeenth century. We may not agree with Sir William Willcocks about his emphatic statement that this river was really an 'overflow irrigation canal', brought into being by the greatest irrigation expert of ancient times, Bhagirath, for the simple reason that a detailed survey of the river in the field has revealed its true riverine character and that was according to ancient tradition. The Bhagirathi-Hooghly down to its mouth, the Ganga Sagar, is still held sacred and given the same sanctity as given to the Ganga higher up. It is, therefore, more likely that the name 'Bhagirathi' as applied to the principal Himalayan headwater of the Ganga was given to its lower reach as well. The name 'Hooghly' was given to the lower reach of the river by English sailors only in 17th century after the great emporium, Hooghly of that century. In fact, the name Bhagirathi-Hooghly may as well be replaced by the word, lower Ganga or simply Ganga by which name it is known to the common people of India.

It is, however, a small point. We should be thankful to Sir William Willcocks (1926) who in his four lectures addressed to Calcutta University some four decades back, on *Ancient System of Irrigation in Bengal*, brought out forcefully the need to resuscitate the declining distributaries of the Ganga, the Bhagirathi-Hooghly, Jalangi, Mathabhanga and Garai, if Bengal were to prosper agriculturally and industrially, and that he even agreed that a barrage on the Ganga might have to be constructed for solving the river problem of Bengal when, of course, the country could afford to have it. The time has now come and the barrage at Farakka has almost been completed and it is expected that the Farakka feeder canal will greatly benefit the people of the Bhagirathi-Hooghly basin.

A reference may be made to the intensive survey of the river system carried out by Major James Rennell, the first Snrveyor General of India between 1765 and 1773, and especially to the maps prepared by him which are of great historical importance and vividly tells us about the changes in the river courses of Bengal, especially the Bhagirathi-Hooghly. Since Rennell's time the rivers of Bengal have further deteriorated and changed their courses considerably. Rennell's remarks on the river of Bengal are no longer true. He wrote "the Ganges and Brahmaputra rivers together with their numerous branches and adjuncts intersect the country of Bengal in such a variety of directions as to form the most complete and easy navigation that can be conceived. So equally and admirably diffused are those natural canals over a country that approaches nearly to a perfect plane that after excepting the lands continuous to Burdwan, Birbhum etc. which may be reckoned a sixth part of Bengal, we may safely pronounce that every other part of the country has even in the dry season some navigable streams within 25 miles at farthest and more annually within a third part of that distance." It is certainly not applicable to the Bhagirathi-Hooghly at the present time as will be pointed by some of our participants, especially by the officers of the Port Commissioners. This point has been dealt within the Report on the Basic Development Plan, Calcutta Metropolitan District, 1966-1986, brought out by the CMPO. It is a known fact that the Bhagirathi-Hooghly river provided the most favourable waterway, much cheaper and easier than overland route at the time Calcutta established its firm-footing on its present site in the 17th century. Ocean liners with a draft of 26 ft could easily approach the City in those days and even during the 2nd World War small steamers were regularly plying from Calcutta to Kalna, a distance of 83 km.

The Bhagirathi being practically cut off from the main Ganga by a sand bar, now carries only the local rainfall except in the monsoonal months when the level of the river water rises above the sand bar. This is corroborated by the fact that dry weather flow of the river is negligible, the average flow in Bhagirathi at Jangipur being 61 cusecs for seven months, December to June, that of the Bhairab-Jalangi at Muktearpur, 100 cusecs, and that of the Mathabhanga at Chuadanga 350 cusecs. The delta building activity of the Bhagirathi-Hooghly must have been stronger in its mouth than in the mouth of the combined waters of the Padma-Meghna in East Pakistan (Bangla Desh), as indicated by more advancement seaward of the delta-face in the west than in the east. It is reported that further advancement of the delta face in the west has stopped as a result of deposition of silt on the river bed instead of in the open Bay. According to the CMPO report "the Ministry of Irrigation & Power has calculated that from 90 to 100 million cubic feet of silt come into the Bhagirathi-Hooghly every year, two-thirds of which is deposited in the river below Bansberia whence it is pushed up again by the flood tides which reach about 128 km above Calcutta in dry summer and 16 km below Calcutta in the rainy season."

It is also a known fact that the Port Commissioners have to employ specially trained pilots to direct ships to and from Calcutta harbour mainly because of the existence of continually changing sand bars on the bed of the river. We will hear more about this from contributions made by officials of the Port Commissioners, especially the problems of navigation arising during heavy bore tides, and especially affecting deep-draft ships. We shall also be interested to know what steps are being taken by them to enable bigger ships to enter in the port so that the annual turn-over could increase to 15 million tonnes, double of the present turn-over, even after the completion of the Haldia port with its ancillary facilities.

The Bhagirathi-Hooghly meanders all through over its flood plain from its head near Ramkantapur to its mouth at Gangasagar and shows all the typical features of a meandering river. The surface though flat has been unequally graded, there have been more of erosion on the concave bank down the slope of the meandering channel. K. G. Bagchi was the first among geographers to take up this basin for a geographical study. His study of the Ganga delta published in 1944 revealed a close relationship between the dynamic problems of physiography and the people and how cultural landscape could change with the changing physical landscape. Subsequently, he had studied the southwestern part of the Ganga delta enclosed between the Bartala and Matla distributaries in greater detail and found the coastal sand ridges advancing inland, and that the earthen embankments were being undermined by wave action. Further east flows the Adi Ganga, the original course of the Ganga, now almost a dead river, revived as Tolly's Nala. This channel has been traced by Shri Bagchi and a brief reference to its hydrological features was made. He also underlined in one of his papers the three types of drainage in the Ganga delta (i) defunct channels like the Adi Ganga, (ii) dissected and interrupted channels due to human interference, and (iii) primitive channels. Satyakam Sen conducted field research in the Bhagirathi Basin studied the meandering currents of the river and analysed the geomorphological features of the river. A few papers on the Bhagirathi-Hooghly Basin have also been published in the pages of the Geographical Review of India, Calcutta. S. R. Basu is also to be congratulated for his excellent papers on the evolution of the Bhagirathi meanders between Katwa and Nabadwip, that is to say, from the confluence of the Bhagirathi with the Ajay in the north and with the Jalangi in the south. I do not know whether he is extending his research on the fluvial dynamics to other portions of the Bhagirathi-Hooghly. A traverse along the Bhagirathi-Hooghly from Jangipur to Diamond Harbour will reveal that the meandering curves straighten out as it should be with the arrival of more silt-free waters in the river either from its tributaries or from higher rainfall in its catchment basin. The ratio between the straight course of the river as the crow flies and the meandering course as shown on maps based on surveys in 1916-17 differs from 1 : 3 between Katwa and Nabadwip and 1 : 1.25 between Tribeni and Diamond Harbour. By 1950 the meandering channel of the river between Katwa and Nabadwip was considerably narrowed down by cutting through the necks of the meandering loops, as shown on one-inch maps based on surveys carried out in 1950. Another interesting feature is the behaviour of the meandering river as expressed in the ratio between the width of the river and that of the meandering channel, which appears to be on an average 1 : 15 in the Bhagirathi between Jangipur and Diamond Harbour ranging from 1 : 12 to 1 : 20 in different sections, a little more than that of the Rhine, Po and Danube (1 : 18), as calculated by E. de Martonne. Some of the following features, as noted in the Mekong Valley are also displayed in the

Bhagirathi basin. (Leopold, Wolman and Miller, 1964).

(1) "Ox-bow lakes representing the cut-off portion of meander bends", specially between Katwa and Kalna.

(2) "Meander scrolls, depressions and rises on the convex side of bends formed as the channel migrated laterally down valley and toward the concave bank". This is very much pronounced on all the convex bends between Agradwip aud Purbasthali.

(3) "Sloughs. areas of stagnant water, formed both in meander-scroll depressions and along the valley walls as flood flows move directly down-valley, scouring adjacent to the valley walls". These features can best be seen at Dainhat and Patuli.

(4) "Natural levees, raised bermes or narrow shelfs above the flood plain surface adjacent to the channel, usually containing coarser materials deposited as flood flows over the top of the channel banks". These are most frequently found on both the banks of the Bhagirathi between Katwa and Dainhat on the west and between Nakasipara and Muragachcha on thc east.

Besides the meandering channel, the flood plains on either side of the river differ somewhat in their characteristic features For example, the east Bhagirathi plain slopes away from the river and contains more of sloughs and meander scrolls than the west Bhagirathi Plain, fairly well drained by east-flowing channels. These are some of the characteristic features that need further study. Now a word about the Sundarban which occupies the southern portion of the Bhagirathi-Hooghly basin bordering the sea.

Sundarban is intersected by a network of big tidal rivers, the estuaries of which penetrate far inland. Here the rivers flow not in a single channel but in a multitude of cross-connections of rivers which under normal conditions raise the level of the land through which they flow. The Government did not perceive the danger of early reclamation of Sundarban, when it was leased out in large blocks to individuals. Since practically the whole of the Sundarban was below the high water level of spring tides, the reclamation work mainly consisted of the exclusion of tidal salt waters. The fields were enclosed by embankments and the rivers were forced to remain within the channels by artificial banks. Even the smallest water inlets were carefully confined between high embankments. The inevitable result of this interference with the natural channels was the gradual rise of the river beds above the general level of the country making the problems of the drainage and of the maintenance of embankments more and more difficult. The Matla, for example, now lies 3 m. above the general level of the surrounding lowlands, and may break through the embankments any moment, causing disastrous floods. Because of the rise of the thalweg, the depth of this river has also decreased considerably within the last sixty years. In some cases—the embankments once breached could not be repaired with the result that reclaimed arable land once again reverted to marshy area. The Payna marsh which is partially drained by the Karati or Kuriathanga can be quoted as an example.

For planning the development of the Bhagirathi-Hooghly Basin its population pattern and present-day industrial structure are to be reckoned with. The Bhagirathi-Hooghly river serves as the axis of dense urban population in West Bengal. It is true that the population is not evenly distributed today along the axis due to a very rapid development of its southern part in and around Calcutta. In fact, Calcutta is the most densely populated city in the world. The density per square mile being 73,112 as against 37,716 in Tokyo, the largest city of the world, and 28,616 in London, the second largest world city. As a result of extreme localization of large-scale industries along the banks of the river stretching from Tribeni in the north to Uluberia in the south. The population in this part of the Hooghly banks would soon exceed the mark of 10 million. Water supply and sanitation appear to be the main problems of this huge conurbation which alone would cost about Rs. 600 million during the Fourth Plan as reported in today's paper. Away from the river banks long meandering belts of contiguous villages with their surrounding orchards, separated by extensive rice fields characterise the cultural landscape of the Bhagirathi-Hooghly Basin.

The question of the organisational set up for developing the Calcutta Metropolitan area is receiving the attention of rhe Government of West Bengal. There are at present several authorities entrusted with the development of the Bhagirathi-Hooghly basin like the Calcutta Corporation and 35 municipalities, CMPO, Calcutta Port Commissioners and perhaps the Damodar Valley Corporation so far as the western portion of the basin is concerned. It may be worth consideration whether all these could be integrated into one autonomous body for an all-round development of the Bhagirathi-Hooghly basin, for which a Commission need be set up by the Government of India on the lines of the Mississippi River Commission.

Even though this cannot be implemented straight away we can reasonably hope that the deliberations of this Symposium will inspire Indian geographers and other scientists to take up an intensive study of hydrological characteristics of the Bhagirathi basin particularly with reference to fluvial morphology, peculiarities of flood genesis, fluctuation of water table and underground water resources. Genesis of coastal features with reference to beaches, spits and barriers, coastal dunes and especially deltaic forms and structures can also be studied in right earnest.

HYDROLOGICAL CHARACTERISTICS OF THE RIVERS OF THE BHAGIRATHI BASIN

Sri B. Maitra

Although the Bhagirathi-Hooghly river is only a distributary of the Ganga taking off on the right bank of the latter river in the district of Murshidabad it forms the spinal chord so to say, of the truncated State of West Bengal, and wields considerable influence on the socio-economic life of the State, particularly its Central and and Southern portions. It is through this river that a significant catchment area of about 6,700 square miles in the Chotanagpur Plateau as well as the plains area is drained off through the several western tributaries. In fact, the Bhagirathi-Hooghly along with its tributaries constitutes by far the major portion of the system of natural waterways within the State. Its importance cannot, therefore, be over-emphasised.

Out of the 350 miles stretch of the river from the off-take to the outfall into the Bay of Bengal, the upper non-tidal reach of about 150 miles upto Nabadwip goes by the name of Bhagirathi, while the lower tidal reach from Nabadwip to the outfall is known as the Hooghly. The two main tributaries on the left bank i.e. east, are the Bhairab-Jalangi and the Mathabhanga-Churni which in fact take off from the main Ganga further downstream of the Bhagirathi off-take, while the main tributaries on the right, i e. the west, are the Pagla, the Bansloi, the Babla (which brings the combined outflow of the Mayurakshi, Dwarka, Brahmani, Gambhira, Kopai and Bakreswar rivers), the Ajay, the Damodar, the Rupnarayan, the Haldi, and the Rasulpur. In between the Ajay and the Damodar outfalls, there are also the two tributaries formed by the combined streams of Khari-Banka-Brahmani rivers and then the Behula-Gangur-Kunti rivers. The western tributaries bring in a considerable amount of sediment load along with their freshets from the upper catchments and this huge detritus load plays a significant role on the regime of the Bhagirathi-Hooghly system.

Before the twelfth century the main course of the Ganga river used to flow through the Bhagirathi-Hooghly and the Padma which carries the main flow of the Ganga at present, was only a small spill channel of the Ganga. Between the twelfth and the sixteenth centuries, the Ganga flow was divided between the Padma and the Bhagirathi channels, one receiving the major share in some years and the another in other years. However, from the sixteenth century onwards the mainflow of the Ganga is passing through the Padma, leaving the Bhagirathi only as a spill channel. Since then the amount of head water received from the Ganga has gradually diminished resulting in a steady deterioration of the river regime. The Bhagirathi has to-day become a seasonal river being fed by the Ganga only during the rains and supplemented by the freshets of the different tributaries already mentioned.

Off-take

The Bhagirathi is connected with the Ganga through one or more entrances in the right bank of the Ganga. The history of the Bhagirathi off-take has been one of frequent change on account of its being situated on the shelving side of the curved flow of the parent river viz. the Ganga. The offtake has been known to have shifted approximately 24 miles longitudinally and 10 miles transversely on account of the curved flow characteristics. All these changes in the off-taking channels could be ascribed to either of two causes viz., deposition of sand bars at the mouth of the entrance or else a recession of the mainflow of the Ganga from the right bank. Occasionally, the higher elevation of the bed at the downstream end of the entrance channel itself interfered with the free inflow, especially during low and medium stages of the Ganga river. The entrances functioning at different times are Kaliganj, Nurpur, Biswanthpur, Mondai, Chapghati, Chakghat and Nimtita. At present the main off-take is at Biswanathpur. At higher stages some spill water enters the Bhagirathi through the Nurpur channel also.

PART ONE

GEOLOGICAL FRAMEWORK OF THE BHAGIRATHI-HOOGHLY BASIN

SUPRIYA SENGUPTA

Abstract

The drainage pattern of West Bengal indicates a regional south-easterly slope that can be traced in the subsurface to all the Tertiary geological horizons. Movements on a NE-SW trending hinge-zone located at the edge of the stable shelf of the basin were partly responsible for the development of this slope.

A gradual change of basin axis from east-southeast to south-south-east with time, is noticed in the Tertiary. Continuation of this process in the recent times, through unequal movements on the hinge zone, might be responsible for the sharp southerly turn of some of the West Bengal rivers. The Bhagirathi-Hooghly river system flows through a zone of weakness which might have developed as a result of these movements.

The idea of a gradual southerly tilt of West Bengal does not find support in the historical records which indicate an easterly migration of the main flow of the Ganga (from the Bhagirathi to the Padma channel) in course of the last few centuries. It is suggested that this easterly shift is due to blocking of the Hooghly estuary by tidal sand in recent years. The geological processes seem to be in favour of revival of the main flow of the Ganga through the Bhagirathi channel.

Near Sahibganj-Sakrigali, located on the northern side of the Rajmahal hills, the Ganga flows into the extensive alluviated plains of Bengal. The Bhagirathi-Hooghly river system, the westernmost distributory of the Ganga, flows in an essentially southerly direction into the Bay of Bengal, after traversing an extensive area of West Bengal. The geology of this part of Bengal is almost wholly concealed below a blanket of riverine alluvium.

Thanks to the intensive programme of subsurface exploration carried out by the Standard-Vacuum Oil Company, under the Indo-Stanvac Petroleum Project, the history of geological evolution of the Bengal basin since the Cretaceous time, is now fairly well known. The subsurface geology of the Bengal basin as revealed by this exploration, has been discussed in detail elsewhere (Biswas, 1963 ; Sengupta, 1966). The purpose of the present note is to make a brief review of certain aspects of the Bengal basin geology which might help in tracing the stages of evolution of the Bhagirathi-Hooghly river system.

STRUCTURAL UNITS OF THE BASIN

Following is a brief account of the subsurface structural units recognised from west to east, in the western part of the Bengal basin (present West Bengal) :

i) The shield area, which is constituted of the Archaean shield which disappears below a blanket of alluvium approximately to the east of longitude 87°E, but which has been traced below a thin veneer of alluvium, up to a zone passing through Midnapur, Galsi and Jangipur.

ii) The basin margin zone which is marked by some subsurface domal structures of varying dimensions. The zone is bordered to the east by a row of *en echelon* faults.

iii) The stable shelf zone of the basin, which dips very gently to the southeast. Excepting a row of normal faults passing through the Jalangi-Debagram-Burdwan-West Ghatal areas, this zone is practically undisturbed tectonically. The stable shelf is occupied by sediments of Mesozoic and Tertiary (mostly Tertiary) age. These sediments show uniform increase in thickness to the southeast from about 3000 feet near the western margin of West Bengal to about 27,000 feet below Calcutta. The edge of the stable shelf is marked by a zone of flexure (the "Hinge zone" of the basin).

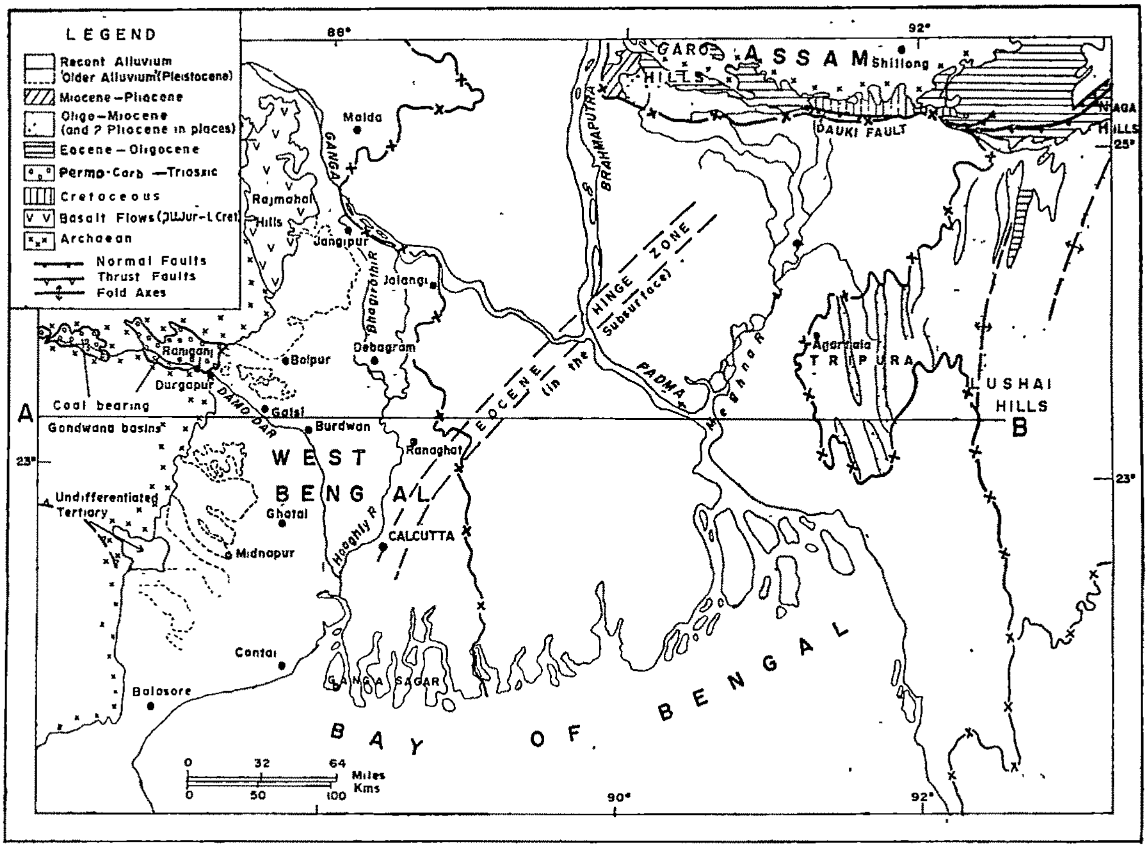
iv) The "deeper parts" of the basin, which lie beyond the hinge-zone, and occupy most of the eastern and southeastern parts of Bangla Desh.

Depositional environments of the Tertiary sediments of West Bengal have been discussed in detail by Biswas (1963) and have been tabulated by Sengupta (1966). Following are some of the salient features of Tertiary sedimentation in West Bengal.

A section of Upper Cretaceous limestones and calcareous shales overlies the extensive basalt flows (Upper Mesozoic) and associated trap-wash, granite-wash rocks near Ghatal, Debagram and Jalangi. These rocks were deposited in brackish marshy, lagoonal or partially littoral environments (Biswas, 1963, p. 244). Near Jalangi, a thick section of freshwater sediment was deposited between two phases of extensive Eocene marine transgressions which covered the whole of the Bengal shelf. During Oligocene, deposition under freshwater to estuarine conditions continued near Burdwan while shallow marine environment (locally deltaic to estuarine) prevailed in the areas further east (Memari-Pandua). During Late Miocene to Pliocene, extensive areas of West Bengal were again transgressed by the sea. During this time, near Debagram and further southeast, deposition took place under deltaic and shallow marine environments. In early Pleistocene, shallow marine conditions prevailed only in the deeper parts of the Bengal basin. Possibly only very late in the Pleistocene did the sea finally recede completely from the Bengal basin, leading to erosion and peneplanation of the late Tertiary deposits.

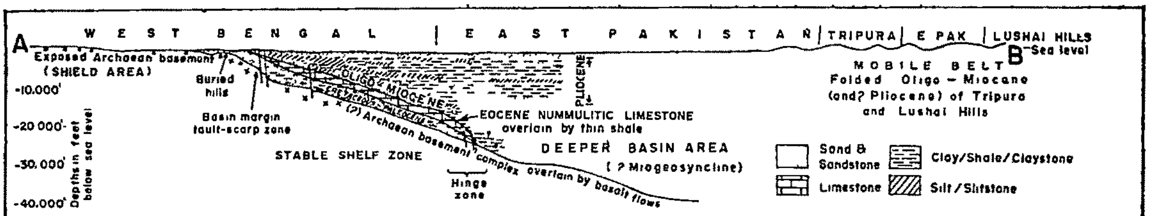
Some broad conclusions regarding the phases of marine transgression on the Bengal shelf can be drawn from the above information. Barring the extensive

GEOLOGICAL MAP OF THE BENGAL BASIN AREA



phases of marine transgression in the Eocene and parts of the Miocene, marine sedimentation during the Tertiary was restricted to the eastern and southeastern parts of West Bengal. Curiously enough, throughout the Tertiary history, the areas around the present Bhagirathi-Hooghly river system seem to have acted as the approximate boundary between the marine and nonmarine areas of sedimentation in West Bengal. Moreover, in the younger Tertiary sediments, a sharp change in lithofacies is noticed in the subsurface, approximately along the present Bhagirathi-Hooghly river system (Biswas, 1963, Fig. 39 ; Sengupta, 1966, Fig. 6). This might mean that the marine transgression on the West Bengal shelf were effected by some tectonic movements lying approximately along the present Bhagirathi-Hooghly river system. This leads, to an interesting question : is Bhagirathi-Hooghly flowing through a zone of tectonic disturbance that was active throughout the Tertiary ?

The NE-SW trending zone of flexure on the Eocene limestone horizon of the Bengal basin, detected at a depth of 15,500 feet below Calcutta, could be the feature mainly responsible for tectonic movements of the West Bengal shelf. The trends of the Bhagirathi-Hooghly river system do not strictly conform to this zone of flexure. It is possible that these rivers follow the resultant zones of weakness developed through a multiple system of movements. This question is examined below in the light of the information obtained from different sources.


A
WEST BENGAL
EAST PAKISTAN
TRIPURA
E PAK
LUSHAI HILLS
B
Sea level
Exposed Archaean basement (SHIELD AREA)
Buried hills
Basin margin fault-scarp zone
-10.000'
-20 000'
-30.000'
-40.000'
Depths in feet below sea level
OLIGO & MIOCENE
CRETACEOUS-PALEOCENE
PLIOCENE
(?) Archaean basement complex overlain by basalt flows
EOCENE NUMMULITIC LIMESTONE overlain by thin shale
STABLE SHELF ZONE
Hinge zone
DEEPER BASIN AREA (? Miogeosyncline)
MOBILE BELT
Folded Oligo – Miocene (and? Pliocene) of Tripura and Lushai Hills
Sand & Sandstone
Clay/Shale/Claystone
Limestone
Silt/Siltstone

CROSS SECTION ACROSS THE BENGAL BASIN TO SHOW SUBSURFACE CONFIGURATION AND BROAD CHANGE IN LITHOFACIES ACROSS THE BASIN

During the phases of deltaic sedimentation in the southeastern parts of West Bengal, rest of the Bengal shelf was under the influence of freshwater sedimentation. The system of rivers responsible for this freshwater sedimentation could be the precursor of the Ganga which might have been flowing into the Bengal plains through the "Garo-Rajmahal gap". Geophysical surveys by the Oil and Natural Gas Commission (Rao and Sengupta, 1964) have indicated the presence of a buried ridge (below the Tertiary sediments) in the area of the Garo-Rajmahal gap. This ridge separated the Bengal basin from the Ganga trough in the north. At least one or more narrow gorges or troughs were detected across this subsurface ridge. It was suggested by Rao and Sengupta (1964, p. 156-157) that during the Tertiary, the Bay of Bengal might have been connected with the Ganga plains through these gorges. On the other hand it is also possible that the buried ridge kept the rivers of the Ganga plains completely separated from the Bengal basin through most of the Tertiary. Only very late in the Tertiary did the post-Siwalik movements in the N. W. Punjab cause a dismemberment of the "Siwalik river" ("the Indobrahm") causing the Ganga to flow in a southeasterly course through the Bengal plains (Wadia, 1961, p. 56).

Seismic studies indicate uniform southeasterly slope of the basement (base of the sediments) for the whole of the Bengal plains (Sengupta, 1966) and also for the area to the south of the buried basement ridge in the region of the Garo-Rajmahal gap (Rao and Sengupta, 1964). A general southeasterly slope characterises all the subsurface Tertiary horizons of the Bengal basin. The present drainage pattern of West Bengal again, clearly indicates a regional southeasterly slope which is apparently the shallower expression of the slope of the Tertiary geological horizons. Whatever be the manner and time of origin of the Bengal rivers, it is now more or less certain that the drainage system of West Bengal was southeasterly throughout the Tertiary.

An interesting feature marks the southern part of the map of Bengal. A number of rivers flowing in the Bengal plains in a southeasterly direction for a considerable distance turn sharply to the south in the southern part of West Bengal. This southerly turn is particularly well displayed by the Damodar and the Rupnarayan rivers. The Bhagirathi-Hooghly river system also follows a southerly course to the sea. The Damodar river which is known to have followed a more or less easterly course till about the mid 17th century, used to join the Bhagirathi at a point north of Saptagram (re : map compiled by Mallik, 1965 ; also the map by Van den Broucke, 1660 in Ray, 1947).

A clue to the southerly tilt of the West Bengal plains through the Tertiary is obtained by a comparison of the trends of the structure contours of the three seismic reflecting horizons (i) the Upper Jurassic (or Lower Cretaceous) horizon, which forms the base of the Tertiary sediments, (ii) the Eocene marker horizon, (iii) the Miocene marker horizon (Fig. 1 & 2). The trends suggest a slight swing of the basin axis from east-southeast to south-southeast through time. This change of basin axis, if it has continued into the recent times, might explain the southerly turn of the Bengal rivers.

Thus, the present drainage pattern of West Bengal appears to be the outcome of two distinct features traceable to the Tertiary history of Bengal—(i) a regional southeasterly slope of the basin, caused, to some extent, by movements on the hinge zone located at the edge of the shelf and, (ii) an increasing rate of southerly tilt of the West Bengal part of the basin due to a relatively greater rate of subsidence of the southwestern part of the hinge through the Tertiary and the recent times.

The idea of an increasing rate of southerly tilt of the Bengal plains however, is not supported by the historical records (Ray, 1947 ; Coleman, 1969), which indicate a gradual eastery migration of the main flow of the Ganga from the Bhagirathi-Hooghly channel to its present course (the Padma) during the last few centuries. Ray claims that till about the 15th century the main flow of the Ganga was through the Bhagirathi-Hooghly channel. This flow might have continued even as late as the 17th century. On the other hand, there are extreme views suggesting that the Padma had been the main channel of the Ganga althrough and the Bhagirathi-Hooghly channels represent artificial irrigation canals of ancient times (Wilcox quoted by Bhattacharya, 1959, p 11). But the general opinion of the more modern workers in the field seem to support the idea of easterly migration of the flow within historical times (Bhattacharya, 1959 ; Ray, 1947).

It must be pointed out that the evidence suggesting an easterly migration of the main flow of water does not necessarily contradict the idea of a southerly tilt of the Bengal plains in recent times. It is possible that the easterly shift of the water flow is due to a process which is unrelated to the southerly tilt of the Bengal plains. For example, blocking up of the Hooghly estuary by tidal sand might be one of the processes responsible for the shift of the main flow of the river into a subsidiary channel. Longshore currents operating along the east coast of India are known to deposit considerable amount of sand in the mouth of the Hooghly. These are moved further upstream, into the Hooghly channel by tidal currents, thereby blocking the normal flow of water into the sea (Chakravarty, 1965, p. 576; Bhattacharya, 1959, p. 47).

If this view is correct, then we have reasons to hope that the geological processes (namely, a continuous southerly tilting of the Bengal plains) operating throughout the Tertiary and possibly continuing even now, are in favour of shifting the main flow of the Ganga into the Bhagirathi-Hooghly channel. Once it is possible to initiate a steady flow strong enough to wash the tidal sands off the mouth of the Hooghly estuary, it should not be difficult to revive the flow of the Ganga through this channel.

REFERENCES

Biswas, B. (1963): *Results of exploration for petroleum in the western part of the Bengal basin*, India, Proc. 2nd Symp. Dev. Petrol. Res. ECAFE, Min. Res. Dev. Ser. No. 18, pt. 1, p. 241-250.

Bhattacharya, Kapil (1959): Vāṅglā-deśer-nad-nadī-o-parikalpanā (in Bengali), Vidyodaya Lib. P. Ltd. Calcutta.

Chakravarty, S. (1965): Paścim vaṅga-pariciti, *Amrita* (Bengali Weekly), 24 December, 1965, Vol. 5, No. 33, pp. 575-580.

Coleman, J.M. (1969): *Brahmaputra river: Channel processes and sedimentation. Sedimentary Petrology*, Vol. 3, No. 2/3 (Special isssue), p. 129-239.

Mallick, S.P. (1965): *Thoughts on the primeval forest, paper submitted to the Symposium on "Sundarbans"* (Directorate of Forests, West Bengal).

Ray, Niharranjan (1354 B.S., 1947): *Vāṅglār Nad-nadī* (in Bengali) [Viśvavidyā Granthamālā], Visvabharati Granthālaya, Calcutta.

Rao, M.B.R. and Sengupta, S.N. (1964): Hidden ranges in the Indo-Gangetic plains in *Advancing Frontiers of Geology and Geophysics* (A. P. Subramaniam and S. Balakrishna, editors), Indian Geophysical Union, Hyderabad.

Sengupta, S. (1966): *Geological and geophysical studies in Western part of Bengal basin, India*, Bull. Amer. Assoc. Petrol Geologists, Vol. 50, pp. 1001-1017.

Wadia, D N (1961): *Geology of India*, Macmillan & Co. Ltd., New York. (Revised 3rd edition).

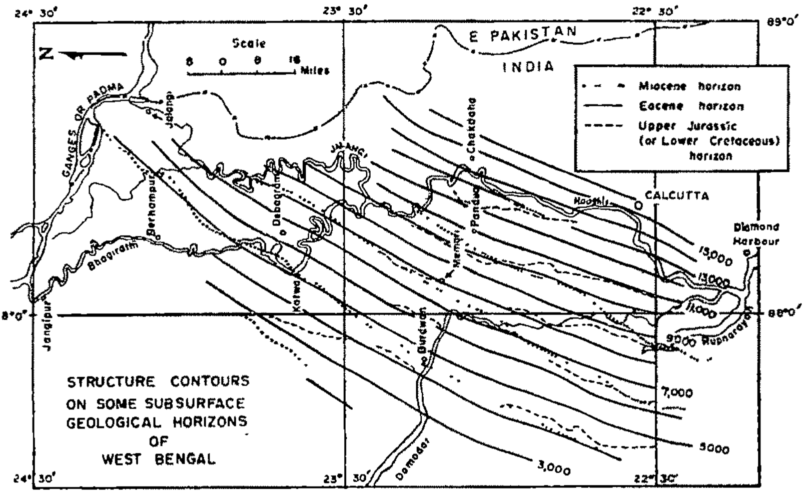


Fig-2 referred to in page-7. Other figures are Fig 1a & 1b.

SEDIMENTATION IN THE AJAY-DAMODAR BASIN

S. DAS

Abstract

The area under study (bounded by latitudes 23°24′ N and 23°37′ N, longitudes 87°20′E and 87°30′E) forms part of the Ajay-Damodar basin, fringing the Peninsular shield on the eastern margin of the Raniganj coalfield. A palaeogeographic reconstruction of the area has been attempted on the basis of the geological information collected from the boreholes recently drilled in the area. The study indicates that after the Raniganj coalfield was faulted down in the eastern parts in the Upper Jurassic and early Cretaceous times, deposition started under fluviatile conditions in the area possibly in the Cretaceous. This was interrupted by a marine incursion in the Lower Tertiary, probably in the Oligocene-Miocene times. As the sea regressed in the Miocene, fluviatile conditions were re-established along the present day courses of the rivers Ajay and Damodar. Erosion left a ridge having roughly E-W alignment, which formed a watershed between the two river valleys during this period. Peneplanation of the area occurred in Upper Miocene and deposition resumed under valley-flat conditions in the Plio-Pleistocene period. Widespread uplift in the Pleistocene times finally established the present day landforms, deposition being confined only along the courses of the rivers Ajay and Damodar.

The Ajay-Damodar basin, which is a sub-basin of the Hooghly-Bhagirathi basin, flanks the eastern border of the Peninsular shield. The area under study forms a part of the Ajay-Damodar basin, and lies between parallels 23°24′N - 23°37′N and 87°20′E - 87°30′E, fringing the eastern parts of the Raniganj coalfield around Durgapur. The rivers Ajay and Damodar follow roughly northwest-south-easterly courses in the area. Laterite, lateritic gravels and alluvium completely conceal the subsurface geology of this area. Exploratory drilling has recently yielded important data which has helped in unravelling the subsurface geology and in depicting the tectonic and depositional history of the area (Fig. 1).

STRATIGRAPHY

The subsurface stratigraphic succession was first described by Das and Biswas (1969), on the basis of lithologs and electric logs of different boreholes in the area, and palaeontological analysis of drill cuttings. With the availability of geological information in the area, the author has partly modified the stratigraphic sequence, which is given below.

Formation number	Formation names	Lithology	Thickness range (metres)	Age
8	Ajay-Damodar	Sand, ferruginous, yellow, coarse to fine ; silt ; greyish yellow clay.		Recent
		.... Unconformity		
7	Bishtupur	Sand, ferruginous, yellow; lithomargic variegated clay ; laterite ; calcareous nodules.	26-45	Pliocene to Pleistocene
		.... Unconformity		
6	Alinagar	Sand and pebbles, greyish white ; grey, sticky clays, with occasional carbonaceous matter.	21-82	Miocene
		.... Unconformity		
5a Tilokchandrapur (eastern parts)	5b Khatpukur (western) parts)	Bluish grey claystones, siltstones, sandstones; calcareous shales, calcareous sandstones, argillaceous and arenaceous limestones, fragmental shell-limestones (eastern parts) 3-95.5 Carbonaceous shales, claystones grey and greyish black, with thin bands of lignite and layers of sand. (western parts)	1-20	Oligocene to Miocene
		.... Unconformity		
4	Kuldiha	Sand and pebbles ; kaolinitic and ochreous sandstones ; red, green and white clays.	2-45	Cretaceous (?) to Oligocene
		.... Unconformity		
3	Durgapur	Felspathic sandstones, coarse to very coarse, gritty and pebbly ; occasional red and green shales ; carbonaceous sandstones, carbonaceous shales, and lenses of dull coal.	0.35-129	Middle Triassic (?) to Jurassic
		.... ?		
2	Panchet	Felspathic sandstones, greyish green, greenish grey, medium to fine ; red and green shales.	51,0	Lower Triassic
		.... Unconformity ?		
1	Raniganj	Felspathic sandstones, greyish white medium to fine ; carbonaceous shales ; grey shales ; a thin lens of coal.	4.50	Permian

The formation numbers 4 to 8 consist of unconsolidated to semiconsolidated sediments, deposited over a basement, comprising members of the formation numbers 1 to 3. The basin deepens to the east and south-east. The characteristics of the different rock units have already been described by Das and Biswas (1969). It should be noted that the formation No. 3 which was previously described as Molangdighi formation, has keen renamed as Durgapur formation since the members of this formation are correlatable with the Durgapur beds, occuring in the vicinity.

MAP SHOWING LOCATION OF BOREHOLES IN THE ALLUVIAL FRINGE, EAST OF DURGAPUR.

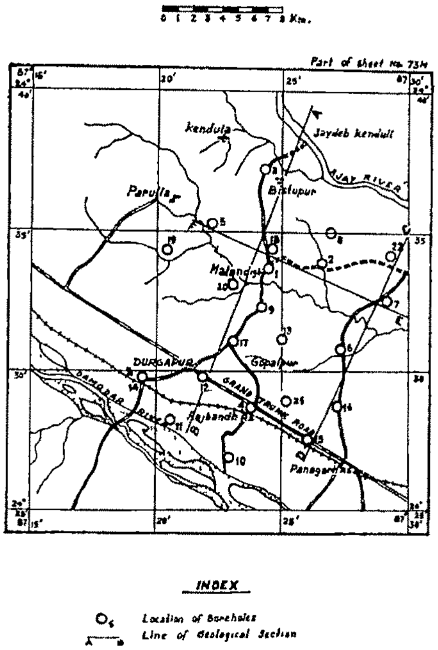


Fig. 1

Geological sections drawn along lines AB, CD, and EF (Fig. Nos. 2, 3, 4) clearly reveal the stratigraphic and structural relationships of the different formations.

TECTONIC AND DEPOSITIONAL HISTORY

A critical study of the geological sections drawn in the area, along with the study of the lithology and palaeontology of the different borehole samples in the area, has brought to light the tectonic and depositional history of this part of the Ajay-Damodar basin. The Gondwana sedimentation in the Raniganj coalfield area, which started in the Upper Carboniferous, continued upto late Jurassic. After the deposition of the Panchets in Lower Triassic, the Gondwana basin distinctly shallowed up, as the deposition of the sediments of Durgapur formation (Durgapur beds or Supra-Panchets) started. With the cessation of Gondwana sedimentation in the Upper Jurassic, the Raniganj coalfield was faulted down in the eastern parts, and on this continental platform started erosion and deposition of the succeeding periods. Borehole records show that barring a marine incursion in Oligocene-Miocene times, sedimentation occurred under continental framework from probably Cretaceous upto Recent. Though these sediments do not record evidences of deformation repeated uplift and denudation of the formations occurred in different periods since the Cretaceous. As a result the structural and tectonic features of the different formations vary. Thus the sedimentary history of the Ajay-Damodar basin possibly dates back to Cretaceous times.

Freshwater, fluviatile sedimentation which started on the continental platform probably in Cretaceous, continued uninhibited upto Oligocene. These sediments belonging to the Kuldiha formation,

GEOLOGICAL SECTION ALONG LINE AB

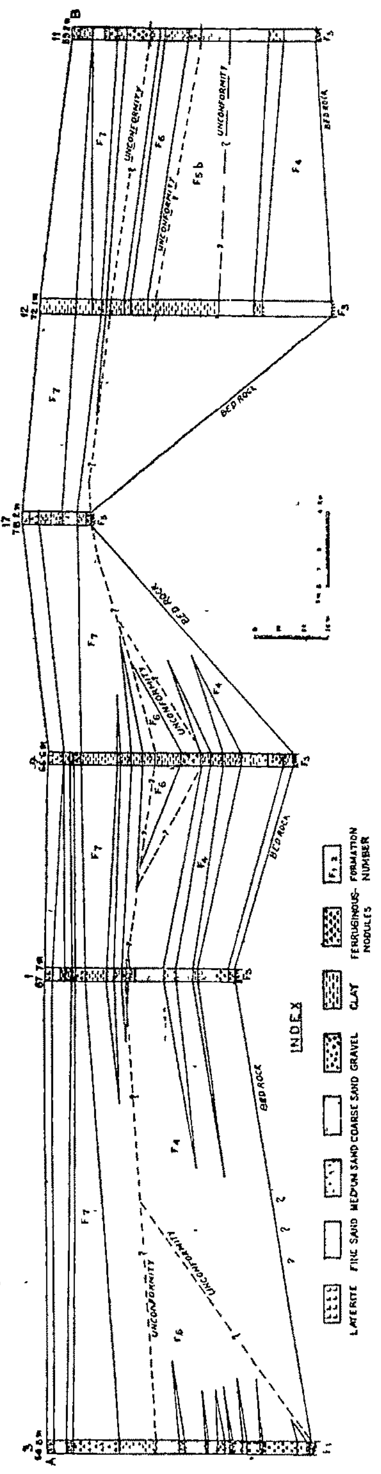


Fig. 2

consist of sand and pebbles, ochreous and kaolinitic sandstones; red, green and white clays, which were possibly derived from the granitic terrain in the neighbourhood. Occurrence of kaolin in the clays distinctly indicates an acid environment of deposition (Millot, 1952). The basement profiles, as revealed in different geological sections indicate that the depths-to-basement increases from 35 metres in the west around Arra to more than 150 metres in the east. Basement highs and scarpings were noted around Arra (Borehole No. 17), Dhabani (Borehole No. 5), and Durgapur (Borehole No. 14), in the west which lose prominence in the east. This post-Gondwana and pre-Cretaceo-Tertiary remnant topography influenced the sedimentation of the Cretaceous and Tertiary times.

After the deposition of the Kuldiha formation, the eastern parts of the area were inundated by the sea, the western extension of this marine incursion was limited by a fault-scarp trending roughly NNE-SSW, and traversing the continental platform between Molangdighi (Borehole No. 1) on the west and Rakshitpur (Borehole No. 2) & Dhoadanga (Borehole No. 13) on the east. The marine incursion started in Oligocene and continued upto Miocene. The faulting which controlled sedimentation of this period, was partly concomitant with the deposition of the Kuldiha formation and partly post-dated it. Its occurrence was indicated by the abrupt steepening of the gradient of the basement between Molangdighi and Rakshitpur in the WNW-ESE section EF (Fig. 4); and by the presence of jointed, fractured sandstones with evidences of mineralisa-

GEOLOGICAL SECTION ALONG LINE CD

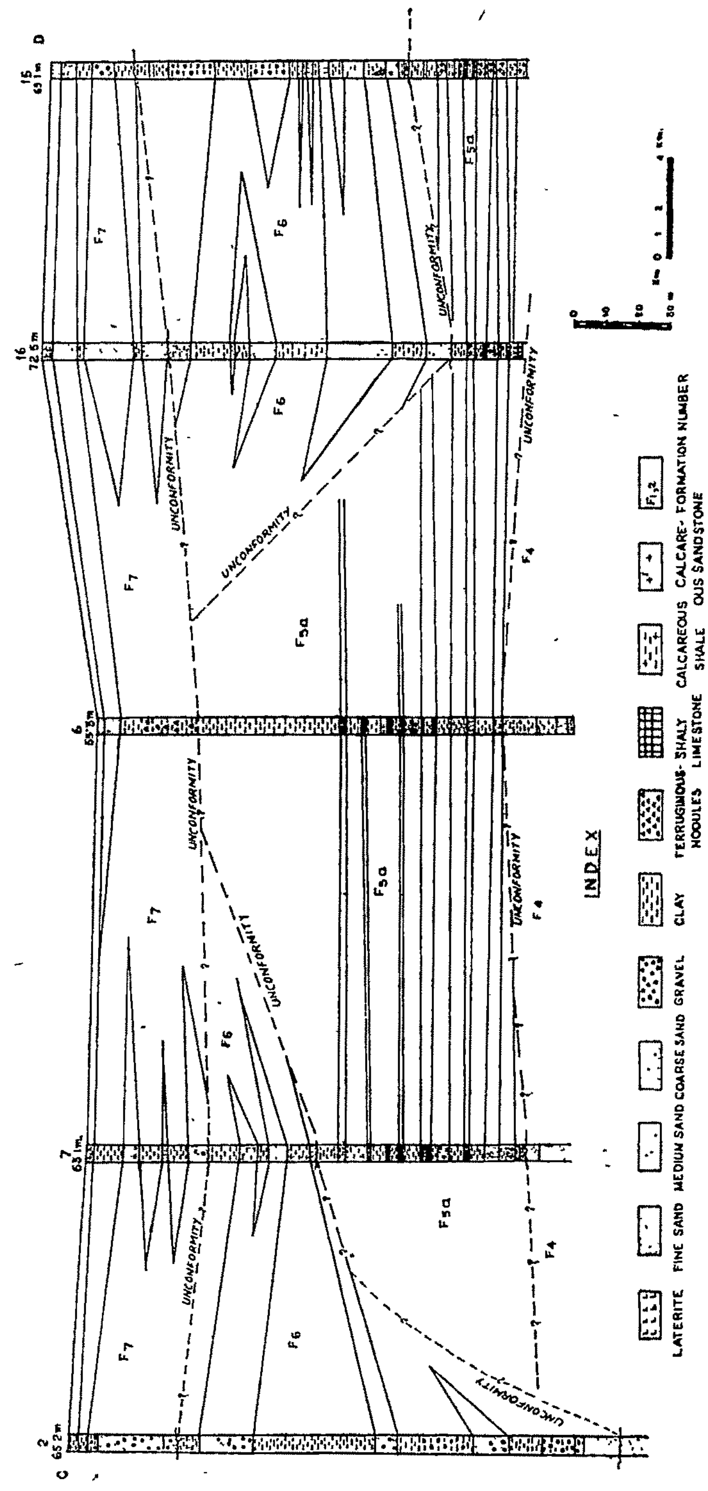


Fig. 3

GEOLOGICAL SECTION ALONG LINE EF

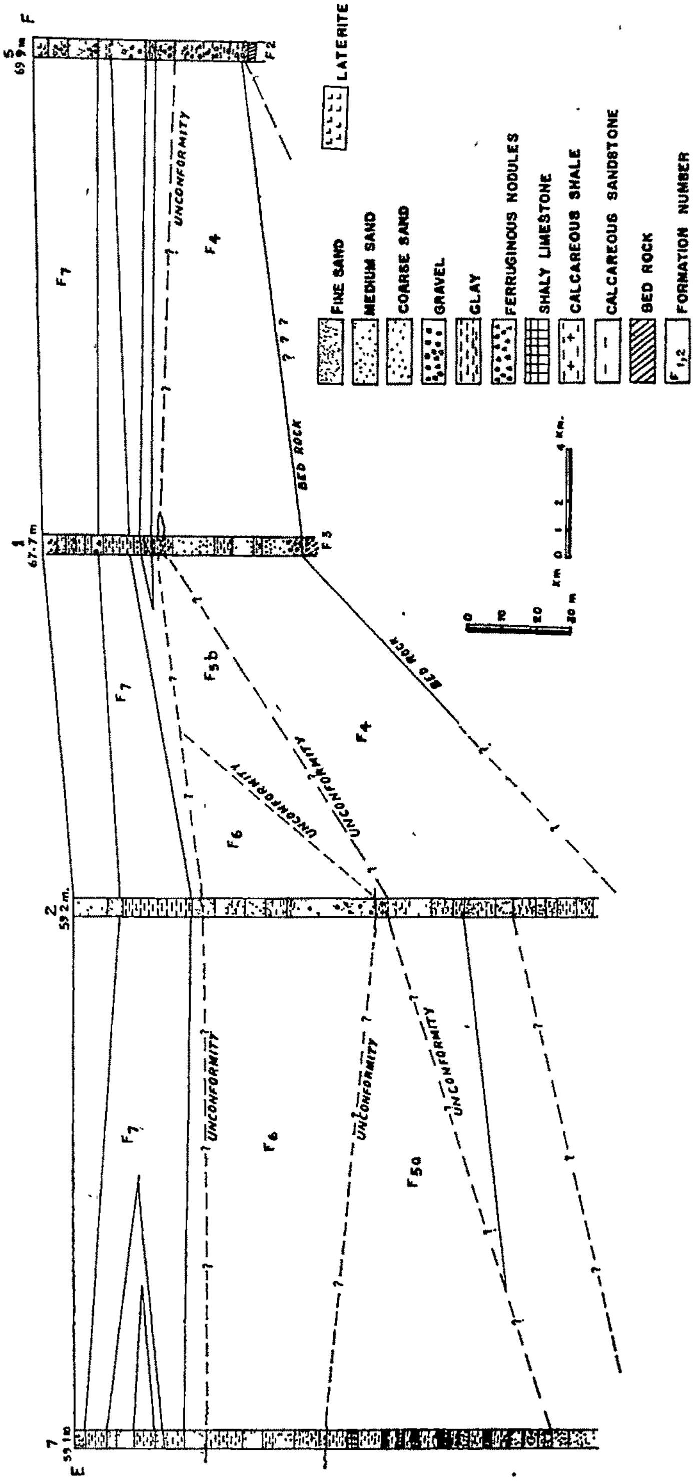


Fig. 4

tion and silicification in the borehole No. 9 at Kuldiha. East of this fault line occurred a sequence of this alternations of foram-bearing argillaceous limestones, arenaceous limestones, calcareous shales, calcareous sandstones, and bluish grey claystones etc. This is a typical stable shelf association. A generally open marine deltaic environment prevailed, but frequent oscillations of the eustatic level of the sea or oscillations in the basin floor during adjustments to faults and fissures occurred. These faults and fissures were actually active since late Mesozoic times. Records of Hystrichosphaerids in the associated mioflora, and occurrence of Rotalia in the limestones point to the marine influence of these sediments. Further the reported occurrence of the clay type like illite also indicate a basic environment of deposition (Millot, 1952).

In areas located west of the fault line, brackish water lagoonal conditions occurred, as carbonaceous shales, claystones with bands of lignite and sandstone of the Khatpukur formation were deposited. The sea probably regressed in Miocene.

In the later parts of Miocene fluviatile conditions were re-established in the area. Sedimentation occurred in areas adjoining the present day courses of the rivers Ajay and Damodar. The deposits of this period are represented by the Alinagar formation, which comprises sand and pebbles, alternating with grey clays, occasionally carbonaceous. The different layers show abrupt thickening and thinning and intertonguing relationships. The sand consists mostly of quartz grains, coarse to fine, angular to subrounded. Quartz pebbles, fine to medium are common. White felspar is also frequently noted in the sand. Erosion of the Tilokchandrapur formation which predated Alinagar formation left a ridge having roughly E-W alignment and traversing the central parts of the area around Dhoadanga (Borehole No. 13) and Tilokchandrapur (Borehole No. 6). This ridge actually formed a water shed between these two river valleys during Miocene (vide Fig Nos. 2 & 3). The sediments in the northern valley included frequent subangular pebbles of basalt. The sediments in the northern valley were in part derived from the Rajmahal Trap terrain. However the metamorphic terrain and the Gondwana rocks in the vicinity formed the major source of sediments during this period. The angular to subangular nature of the sand grains and the presence of white felspar indicate that the sediments attained little maturity. Further occurrence of Schizeaeceae, Polypodiaceae, Parkeriaceae in the mioflora associated with this formation point to a fresh water, swampy habitat. Reported presence of conifer in this flora indicates raised topography and initiation of cold climate, which attained its peak through Pliocene in Pleistocene.

Thus the open large basin of deposition of Cretaceous and early Tertiary times became segmented into two parts in Miocene. The drainage pattern in Miocene was very similar to that of the present day.

At the close of Miocene, uplift and erosion occurred in the basin of deposition. The sediments belonging to the Bishtupur formation were deposited in the succeeding Plio-Pleistocene period, under valley flat and deltaic conditions. In contrast to the previous period the entire area was the site of deposition. The sediments included yellow, ferruginous sand, lithomargic variegated clays. Laterite and calcareous nodules occur at the surface. The abundant ferruginous material in the formation was derived from the trappean flows in the adjoining areas (Gee, 1932). The different layers show abrupt thickening and thinning, and intertonguing relationships. This formation is frequently current bedded as exposed in nallah sections. Two to three cyclothems of sediments, marked by coarse sand and pebbles at the bottom and fine sand and silt at the top were recorded in this formation in some of the boreholes, indicating thereby two to three phases of active sedimentation consequent on repeated uplift and denudation. These possibly can be related to the sealevel fluctuation and rejuvenation of depositional cycles in Plio-Pleistocene times.

The sediments of Bishtupur formation were deposited under oxidising environment and were derived from the metamorphic and Gondwana terrain in the vicinity.

Widespread uplift during Pleistocene finally established the present day landforms. Lateritisation of the sediments is active since Pleistocene. Sedimentation of the Recent times is restricted to the river channels of Ajay and Damodar. These rivers follow broadly braided courses with well developed point bars and swales.

CONCLUSION

The Ajay-Damodar basin came into existence probably as early as Cretaceous. It preserves a full sequence of sediments ranging in age from probably Cretaceous to Recent. The sediments were deposited under a continental framework except during a short period in Oligocene-Miocene, when marine incursion took place. The cycles of sedimentation have been periodically reactivated consequent on the uplift and denudation of the area in different periods.

The drainage pattern as early as Miocene was very similar to that of the present day.

The present day landforms were finally established during Pleistocene.

The sediments were mainly derived from the metamorphic and Gondwana terrain, and partly from the trappean country in the vicinity.

ACKNOWLEDGEMANT

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REFERENCES

1. Biswas, B (1963) : Results of exploration for petroleum in the western part of the Bengal basin, India (Proc. 2nd Symp. Dev. Petrol. Res, ECAFE, Min. Res. Dev. Ser. No. 18, pt 1 p 241-250).

2. Das, S and Biswas, A,B. (1969) : Geology and groundwater conditions of the alluvial tract, east of Durgapur, Burdwan district, West Bengal—A preliminary study (Indian Geohydrology, Vol. 5, No. 1, December, 1969).

3. Das, S (1971) : Subsurface geology of the area, east and north-east of Durgapur, Burdwan district, West Bengal (Proc. Ind. Sc. Cong. 1971).

4. Das, S and Chandra, A (1971) : Mioflora from the carbonaceous shales in the borehole at Molangdighi near Durgapur, West Bengal (Symposium volume on Palaeopalynology and Indian stratigraphy, 1971—in the press).

5. Das, S (1970) : Report on the geohydrological investigation in the alluvial fringe, east of Durgapur, Burdwan district, West Bengal (Unpublished progress report of Geological Survey of India for the field season 1969-1970).

6. Gee, E. R. (1932) : The geology and coal resources of the Raniganj coalfield (Mem. Vol. 61, Geol. Surv. India).

7. Millot, G(1952) : The principal sedimentary facies and their characteristic clays, Clay Min. Bull., 1, p. 235-237.

A STUDY OF THE AJAY RIVER SEDIMENTS

ASOKKUMAR BHATTACHARYA

Abstract

This paper presents the results of a study of the morphology, texture, structure and mineralogy of the Ajay River sediments. Ajay, a tributary of the Bhagirathi, is a meandering river with a length of approximately 180 miles flowing in a general south-easterly direction over three successive lithological terrains, viz., the Archaean gneissic complex, the Gondwanas, and the Older and Recent alluviums. A gradual increase in the sinuosity of the river is noticeable from the headwater reaches (1000 ft. altitude, L/A=5.1) to the mouth (50 ft. altitude, L/A=1.7) of the river. A special study has been made of the sediments forming the crescentic point bars. Sampling in the point bars shows that sand (2-.06 mm.) forms the main part of the bed-load. Two deficient size-grades are noticed at 2-2.83 mm, and 0.125-.088 mm. respectively. The mean size (Mz) decreases with distance of transport while sorting increases with it. The increase of particale roundness with the decrease of size in individual samples is interpreted to be the result of source rock control The sediments show a number of primary sedimentary structures, e.g., ripples and dunes of various types and dimensions, flat-beds, rill-marks, mud-cracks, cross-beds of various types, parallel laminations, deformed laminations and ripple-drift laminations. The dominance of ripples and dunes suggests a lower flow regime (Simons, Richardson and Nordin, 1965) of the river. A tentative cycle of fluvial sedimentation from sedimentary structures has also been proposed. Mineralogically, quartz constitutes 80-85%, felspars 15-20% and heavy minerals 3-5% on the average. Heavy minerals reflect the provenance nicely. Amphiboles, tourmalines. opaques (heterogeneous), epidote, zircon, garnet, are the heavy minerals that come in order of abundance in the transported sediments. A few grains of kyanite, sillimanite, rutile, apatite and monazite are also found.

The present work is an attempt to study the transportation and deposition of the sediments in the river Ajay flowing through Bihar and West Bengal, India. No previous work exists on detailed aspect of sediments in this river.

PHYSIOGRAPHY & MORPHOLOGY

The Ajay starts from Sarwan, west of Deoghar in the Chotanagpur plateau, and passes through the Santal Parganas district of Bihar, Birbhum and Burdwan districts of West Bengal and ultimately meets the river Bhagirathi at Katwa, flowing in a general SE direction for a total length of about 180 miles. The river in course of its journey receives many tributaries on both sides and traverses through three different lithological terrains from the source to the mouth. At first it passes through the Archaean gneissic complex (biotite gneiss, hornblende gneiss, pyroxene granulite, basic intrusives, pegmatite and quartzite) for 120 miles, then over patches of Gondwana sedimentary rocks (Arkosic sandstone, shales, coals etc) for 20 miles and over the older alluvium, (Bolpur sandstones, shales, concretions, laterites) and recent alluvium (sand, silt etc.) for the rest of its course (Fig. 1, map showing studied areas).

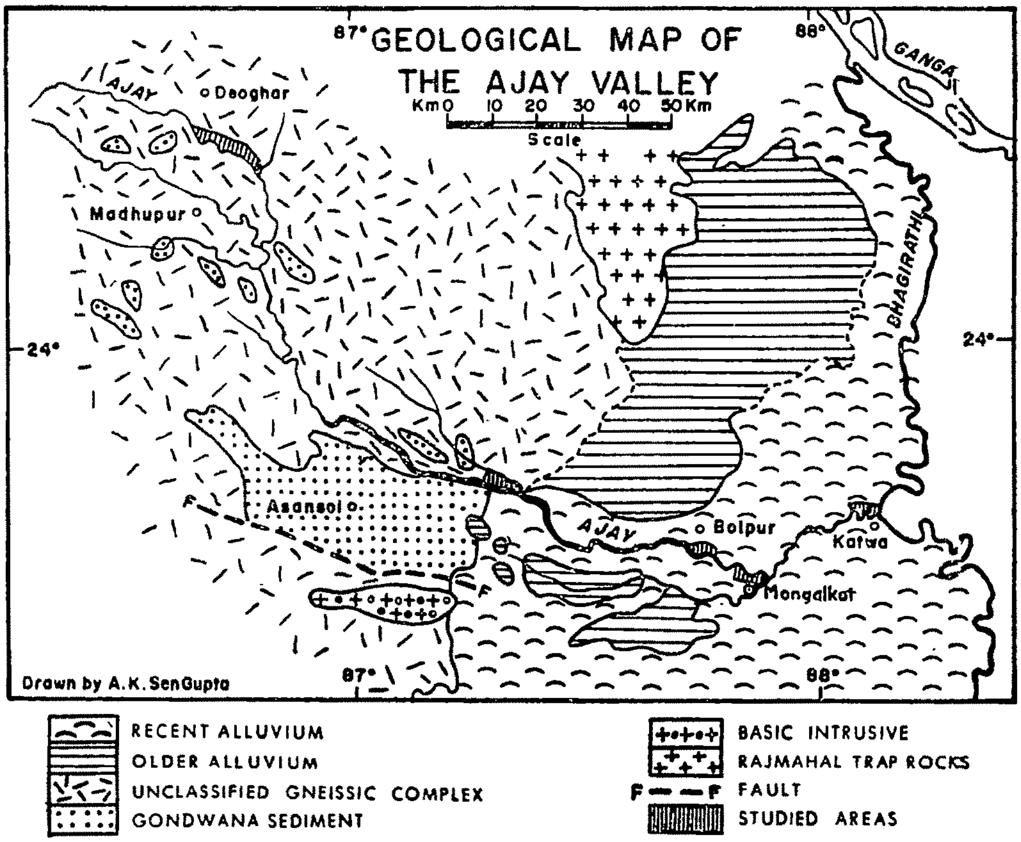
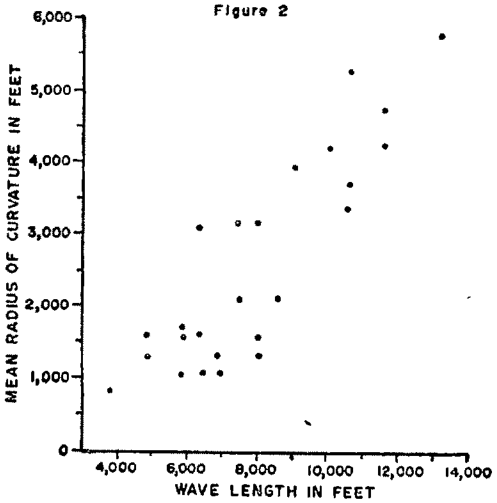


Figure I

The river is a meandering one with variable widths ranging from 100 ft. to 500 ft. The L/A ratio (wave length divided by amplitude), a measure of the sinuosity of the meanders, gradually decreases from the head water region to the mouth. The mean L/A ratios of meanders are 1.7, 3.7 and 5.1 at Katwa (mouth), Bolpur (at a distance of about 35 miles from the source) and Deoghar (at a distance of 5 miles from the source) respectively (for a stretch of 5 miles in each area). The plotting (Fig. 2) of wave length (L) of the meanders against mean radius of curvature (Rm) shows a positive linear correlation between the two i.e., with the increase of wave length, the mean radius of curvature also increases appreciably which is a general rule for meandering rivers. The topography is undulatory with an altitude of about 1000 ft. near the source to 50 ft. or slightly less at the mouth. The longitudinal profile of the river is shown in Fig. 3A. The average gradient is low with a gentle south-easterly slope. The slope is not uniform all along. The plotting of slope Ψ (Ψ=a/b where 'a' is the vertical fall and 'b' is the horizontal unit distance) against D, the river distance in miles (Fig. 3B) shows that from the source upto a distance of about 55 miles downstream, the slope is uniformly steep. From there upto a distance of 130 miles downstream the slope is non-uniform with anomalous increase in slope at two sites, one at 70 miles and the other at 115 miles from the source. These two anomalies in slope are thought to be the reflections of the change of lithology in the river bed. The Gondwana sedimentary rocks occur as patches over the river bed at these two localities of the Ajay Valley. From there upto the Ajay-Bhagirathi doab, where it flows over the alluvium, the slope is uniformly gentle.

Figure 2



DEVELOPMENT OF MEANDERS

The point-bars are associated with the meander bends and are generally crescentic in appearance with variable length, breadth and height from the water-level. At places the river is braided in nature with the development of 'channel islands' or 'bars' within two meander bends. The channel islands usually are 2″—6″ high from the normal water level. It has been realised by Leopold & Wolman (1964) and by other authorities that flow in meandering streams are in two different directions : (1) primary downstream flow and (2) secondary helicoidal flow. Point-bars which are the products of lateral component of the helicoidal flow, grow only where the river deviates appreciably from a straight course. Where the deviation is small, velocities are fairly uniform throughout the channel cross-section and growth of point-bars is minimal (Kolb, 1963). Hence, point-bars are poorly developed in the headwater region where the river course is fairly straight. They are concentrated in the dominantly meandering part of the river near the mouth.

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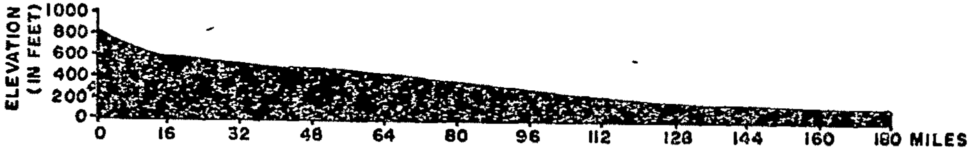
CHANGING COURSE OF THE RIVER

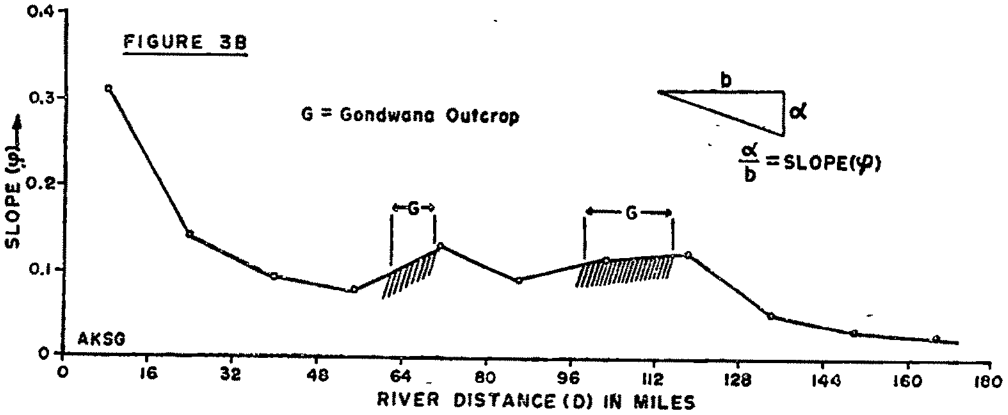
With time the river has changed its course quite often in the downstream reaches. No shifting of the course is known where the river flows over the Archeans and Gondwana terrains. On the contrary, excellent "old-channel" and 'cut-off' are seen from aerial photographs where the river flows over the alluvium (Fig 4). Morphology and texture of the sediments. at Kesia point-bar 2 miles upstream from the mouth also give evidence in favour of this migrating course. Here at Kesia, the river is seen to cut an older point-bar formed during an earlier course of the river and now located abnormally on the convex side of the meander bend. Other evidences also point to several changes in the river course.

FIGURE 3A



LONGITUDINAL PROFILE OF THE AJAY RIVER

FIGURE 3B



WATER DISCHARGE AND LEVEL OF THE AJAY RIVER

The data on water discharge at the Nutanhat gauging station (20 miles upstream from the mouth of the river) for each day during 1966-1968 and daily discharges of the wet months from July to October at Illambazar gauging station (50 miles upstream from the mouth of the river) for five consecutive years (1961 to 1965) were available to the writer from the River Research Institute, Calcutta. The data clearly demonstrate the fact that the Ajay maintains high average discharges during the two months, August and September (freshets) of every year. Subsidiary freshets occur annually during the months of June, July, October and early November. The Ajay has rather very low discharge from December to

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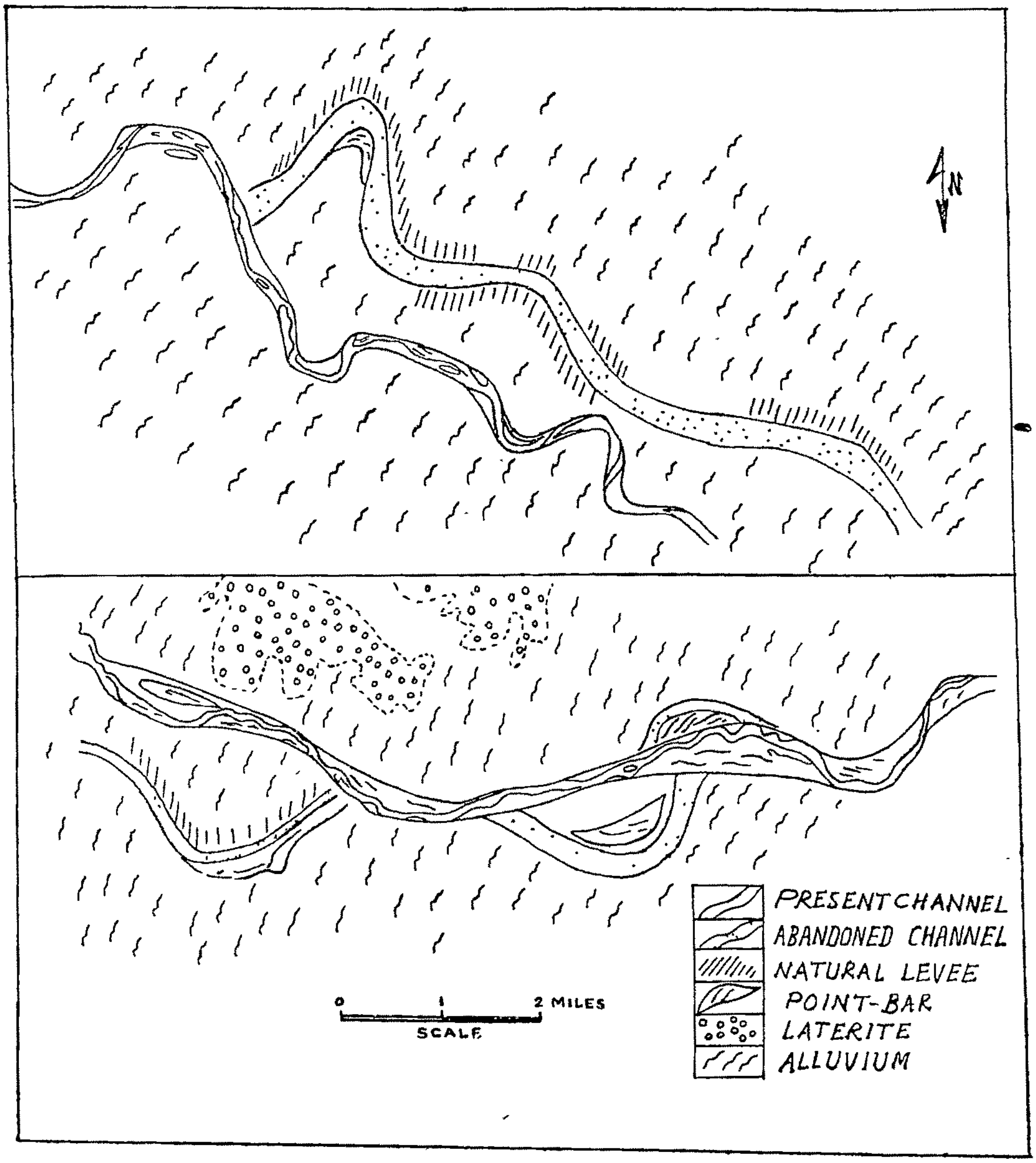

Fig. 4

April. The data of the average daily discharge expressed in cusecs for the rainy season (July to October) for the five consecutive years (1961 to 1965) at Illambazar and also for the three consecutive years (1966 to 1968) at Nutanhat (Mongalkot) indicate a rhythmically fluctuating nature of discharges from alternate peaks and valleys (Fig 5) in the curves for the periods concerned.

The river-level (R. L.) runs close to the thalweg level (thalweg is 15.3 m. at Nutanhat) during the dry seasons characterised by low discharges while the river-level significantly rises during the wet seasons of highest discharge (mean R. L. is 18.6 m. for the years 1966 to 1968 at Nutanhat). During the peak discharge months (August to September), the river level actually rises maximum to a height of 5 metres which may last for only a very few days to overflow the banks and the high sand-bars. It is to be noted, however, that the dates of the attainment of maximum river level are not always exactly the same as the dates of the highest discharge.

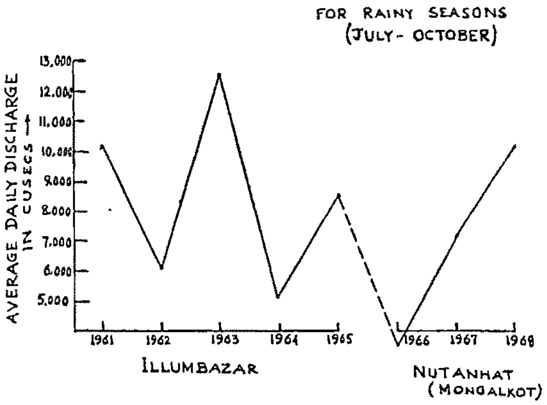

Fig. 5

TEXTURE OF AJAY SEDIMENTS

Systematic bulk sampling has been done from different reaches of the river representing possible diversities in texture of the sediments. 102 such representative samples have been mechanically analysed using sieves of 0.5 or $\sqrt{2}$ mm. diameter. The sieving has been performed by an electric shaker. The sand fractions are weighed and cumulative curves have been prepared using arithmatic probability paper in order to have accurate reading from the stretched tails of the curves. The textural parameters as mean size (Mz), sorting (σ_1), graphic skewness (Sk_1) and kurtosis (Kg) have been calculated using the formula of Folk & Ward (1957). The table 1 gives the distribution and amounts of the gravel, sand and finer fraction in the samples drawn from various points of the Ajay river.

Table 1

Sample ocation	No. of samples	Largest size in mm,	Average % present with range in brackets.		
			Gravel fraction >2 mm.	lsand fraction 2-0.06 mm.	finer fraction <0.06 mm.
Deoghar	16	16 or over	9.5 (.02-24.6)	90.4 (75-99)	0.1 (.06-2.8)
Asansol	41	8 or over	6.5 (.04-19.4)	93.3 (80-98)	0.2 (.08-3.5)
Bolpur	11	2.83	0.28 (.02-.56)	98.9 (97-99)	0.8 (.08-1.8)
Mongalkot	10	2.83	0.20 (.08-.23)	97.8 (97-99.3)	2.0 (.07-4.0)
Katwa	24	2.83	0.20 (.18-.29)	97.6 (97-99.8)	2.2 (.15-.25)

Fig 6 shows the cumulative curves of samples from five localities covering the entire length of the river. The average cumulative curve for each of Bolpur, Mongalkot and Katwa areas is essentially an entirely lognormal one with only a minor coarser tail accounting for less than 1% of total material and containing grains and fragments larger than 0.71 mm. This is in contrast with both Deoghar and Asansol samples that have yielded sharp deviation from lognormality with particles larger than 0.71 mm. sizes. Sharp breaks (inflection) at 0.71 mm., 0.125 mm., 0.088 mm. are noticable in all average cumulative curves, while breaks at much coarser sizes at 2 mm. and 2.83 mm. are also present in the Deoghar and Asansol samples. The materials in the size range 2-2.83 mm. and .088-.125 mm. represent deficient size grades in the Ajay sediments. The presence of these two deficient size grades in the sediments of the higher reaches of the river has given rise to trimodal distribution with the primary mode at .25-.35 mm. and two very subordinate modes at 2.83-4.00 mm. and .088-.062 mm. The sediments of the lower reaches, however, due to absence of the coarse fraction, show bimodal distribution, the primary mode being at 0.25-0.35 mm. and a secondary

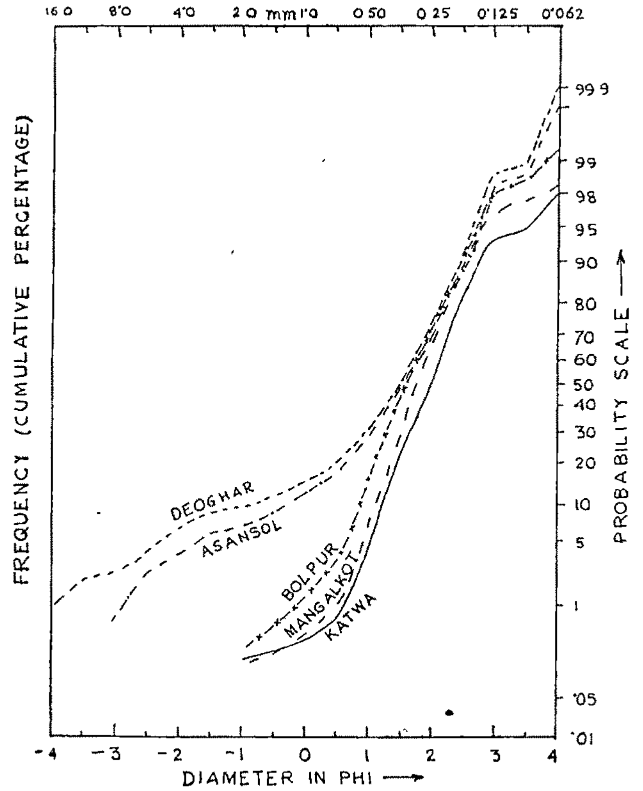

Fig. 6

mode at 0.88-0.062 mm. The deficiency of the size in the 2-4 mm. is common however, in many fluvial sediments due to instability of grains by break down at this size. But the deficiency grade at .125-.088 mm. is characteristic of the Ajay and is a function of the negative size-roundness relationship (i. e., finer size being better rounded) of the Ajay sediments (Bhattacharya, 1969, 1970). The major inflection at 2 mm. is at the transition point of sand and gravel sizes characterised by two different modes of sediment transport (Moss, 1963). The inflection at 0.125 mm. is due to abrupt change in law governing the rate of settling of particles in water at the size 0.1 mm. Lane (1938) has shown that below a size of approximately 0.1 mm., the sand settles at a rate which varies as the square of the diameter and above 0.3 mm. at a rate which varies as the square root of the diameter of the settling particles.

The size reduction of the coarser constituents of the sediments contribute to the formation of solely the sand-sized fraction of each sample of sediment. If any contribution to the silt-sized fraction is visualized, this has to be governed by a law of particle transportation different from that of the bed-load (suspension *vs* bed-load transport). Confirmation is available, from the study of the Ajay sediments, on the cause of production of silt-sized fraction in a sediment by the mechanism of splitting of material of larger grains (i.e., by chipping process) and not by "progress in size reduction of coarse material" as held by Rogers *et al.* (1963). A study of the size-roundness relationship of same sediments by the writer (Bhattacharya, 1969) clearlybrought out an abrupt inflection in particle roundness (measured by Wedell's grains projection method as well from Power's chart comparison) with striking angularity of grains below 0.062 mm. (lower limit of sand size) size—a feature attributable to particle disintegration presumably from collision between particles of the suspended load. The negative size—roundness relationship of the Ajay sediments is explained as the result of original source rock control with little effect of transportation. Hence roundness is thought to be no indicator of maturity of sediment as suggested by Pettijohn (1967).

The size parameter Mz (mean size) of sediments gradually decreases downstream with concurrent increase in (sorting) σ_1 of sediments. The sediment distribution curves of the source areas show mostly negative skewness (though not very significant) due to mixing of the coarse sizes with the main sand-load. While the sediments near the lower reaches show positive skewness (though not very significant) due to the mixture of finer sizes with the main sand-load. This, however, corresponds well with the idea of Spencer (1963) explaining significance of skewness of sediment distribution due to mixing of different populations.

The clay-pellets are derived mostly from the erosion scarps and generally are disc or blade-shaped. Rolling of these pellets in the loose sands of the point-bars in some cases has contributed to their armoured nature with slight modification in shape of the original pellets.

STRUCTURE OF THE AJAY SEDIMENTS

Interest in the study of primary sedimentary structures of recent sediments has greatly increased due to their important bearing on the interpretation of past environment in deciphering the hydrodynamic condition of the river. The important surface and internal sedimentary structures that have been recognised in the deposits of the Ajay are listed in Table 2.

Table 2

Surface structures*	Internal structures*
A. Ripples a) crescentic { linguoid / lunate } b) wavy c) straight d) interfering e) linguloid f) scour or spherical B. Megaripples or dunes a) { oblique or / transverse } b) dome shaped C. Flat-beds D. Flute-marks E. Groove marks F. Mud-cracks G. Channels H. Rill marks I. Larger scours & pools	1. Cross-stratification of various types 2 Horizontal stratifications 3. Convolute laminations and other deformation structures 4. Parallel laminations

The internal sedimentary structures are seen from escarpment and by cutting trenches at suitable directions in the point-bars. It has been seen that the smaller trough cross-stratifications are nothing but the internal manifestation of crescentic ripples. The larger troughs are the products of spoon-shaped or elongated hollows, channel fills, interdune trough-fills etc. The larger planar tabular sets come out when the dunes are cut parallel to the lee slope direction, flat-beds give rise to horizontal stratifications and wedge cross-stratifications are the internal manifestations of the dome shaped dunes produced mostly by wind action.

Among the surface structures, the small-scale ripples are found in the river bed and along the inner banks of the point-bars while the larger-scale ripples or dunes are found mostly over areas along the outer bank of the point-bars. The flat beds are not characteristic of any particular position but often seen to occupy the intervening spaces in between the ripples and dunes (Bhattacharya, 1969). The lee direction of the ripples, dunes and other directional structures are important in indicating the current direction. The writer, from several measurements and observations has come to the conclusion that the smaller crescentic ripples and their corresponding smaller trough cross-beds are the best tools in determining the current direction in unidirectional fluvial environments.

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* For definition of the structures see Allen (1963) and Potter & Pettijohn (1963).

It has been recognised that the ripples are the product of normal flow of the river while the dunes are the product of flood time flow of the river. The ripples superimposed on dunes are the product of waning phase of floods. Thus there is also much variation in the nature of grain size-distribution in different sedimentary structures due to the change in the energy condition of the flow velocities. The grain sizes are finer for ripples (medium to fine sand) than that of dunes (coarse to fine sand) while the grain sizes in horizontal stratifications are very varied in nature (fine to coarse sand usually with pebbles). The parallel lamination are the product of suspension deposition and are usually of fine sand to silt and clay sizes.

Structures due to joint influence of traction and suspension load sediments such as the rippledrift laminations and remarkable planar tabular cross-beds with climbing-ripple laminations on the bottom of the foresets (similar to the type 3 cross-bed of Boersma, 1967) etc. are found on the outer banks (distant flood-plain areas) of the Ajay and they reflect the structures of the intermediate sand and silt size of traction and suspension loads.

Among the deformation structures the planar-tabular cross-beds are deformed with various intensities from simple contortion of forest laminae, through convolute lamination, recumbent folds and intraformational thrusts to convolutional balls. Also the internal laminations of larger trough cross-beds are found to be deformed with minor cremulations at places (Bhattacharya, 1969).

According to Simons & Richardson (1961) the structures as ripples, dunes are products of lower flow regime of the river while the horizontal stratifications are the product of upper flow regime. From the abundance of ripples and dunes and rather rare occurrence of horizontal stratifications of true genetic type, it can be inferred that the Ajay represent a stream of lower flow regime with occassional attainment of the lower limit of upper flow regime condition. From a master diagram prepared by Simons, Richardson & Norden, (1965), it is possible to infer about the range of stream power (vel. X shear stress) from the structure and the grain-size. It has heen found that the stream power (for Ajay ripples) varies between .009-.07 approximately.

The succession of sedimentary structures in vertical sequence is the large-scale cross stratification, horizontal stratifications and small-scale cross-stratification from bottom to top in the point bar deposits The other combination of structures as seen in different trenches are from bottom to top as follows :—

1) larger tabular cross-bed and smaller trough cross-beds, 2) larger trough cross-bed and smaller troughs with a thin band of horizontal stratification in between, 3) larger planar tabular,

horizontal stratification and small-scale planar tabular sets, 4) larger planar tabular, smaller trough and parallel laminations, 5) larger planar tabular, ripple-drift lamination and parallel laminations. All these successions are in accord with the sequences as given by Visher (1965) and indicate a complete cycle of sedimentation representing the period from the high water stage (flood) to normal flow condition of the river.

Table 3

Location	Distance from source	Sample number	% of heavy minerals.
Deoghar	5 miles	a	3.6
Asansol	80 miles	CH 61	3.1
		AB 13	2.7
		AB 21	3.5
Mongalkot	160 miles	P2	3.9
Katwa	180 miles	K3	5.6
		K8	5.2

MINERALOGY OF THE RIVER SEDIMENTS

As regards the mineralogical composition of the sediments on the average quartz is 80-85%, feldspar of plagioclase and potash varities are 15-20% and heavy minerals 3-5%. The amount of feldspar content gradually falls from the source to the mouth while quartz percentage gradually increases towards the lower reaches of the river. The percentage of heavy minerals, though not very significant, increases downstream in general. Table 3 shows the relationship between the percentage of heavy minerals and the distance from the source.

The heavy minerals were separated with bromoform and by the Frantz isodynamic separator. First of all the heavy mineral content in each size grade of individual sample has been separated and then the total amount of heavy mineral present in a bulk sample is calculated. It is found that on the surface of the point-bars as well as on the margins of the river bed, the heavy fraction of the minerals are aligned on the crestal parts of the ripples and dunes with gradual sliding of minerals on the lee side. The stratified units are delimitated by alternate bands of heavy and light fraction of minerals. The most striking feature is this that actually the concentration of heavy minerals controlled by the dynamics of flow is further modified to a great extent in some cases by the post-depositional wind action. This factor plays an important role in case of sediment subjected to surface exposures. Somewhere concentration of black-sand is seen in areas of shallow and gentle-wave condition of water movement.

The Ajay sediments include the following minerals in decreasing order of abundance: amphibole, tourmaline, opaques (heterogeneous group), epidote, zircon, garnet. A few other minerals as kyanite, sillimanite, rutile, apatite, monazite etc. are also found at places. The heavy minerals observed are all found in the source rocks. But pyroxenes which are quite common in the source rocks do not show up in the transported sediment. The reason is not clear but chemical weathering might be the probable cause. The amphiboles in most cases show hack-saw structure indicating the effect of solution.

Plotting of the number frequency curves for individual minerals (by grain counting method) shows a gradual shifting of the curves from tourmaline, the coarsest size to zircon, the finest size. This corresponds well with the increasing density from tourmaline to zircon (Fig 7). This relationship is also borne out from weight frequency curves. This fact suggests that under same dynamics of flow and settling velocity, minerals of high density and finer sizes will codeposit with minerals of lower density with relatively coarser sizes (Sundborg, 1956).

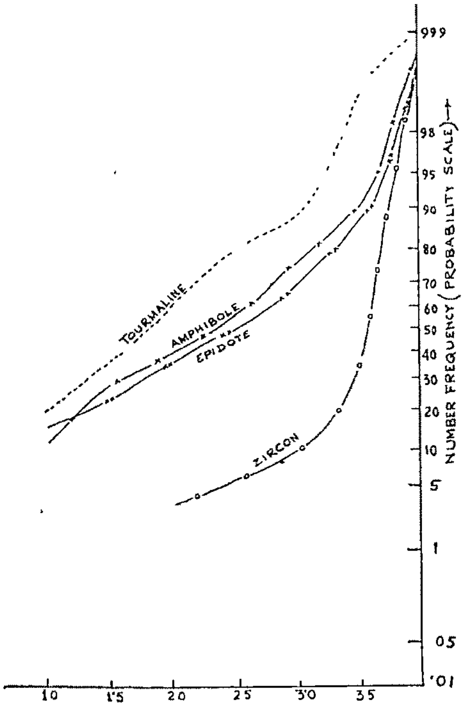

Fig. 7

From the study of heavy minerals a few general observations can be made: the pyroxenes are not found in the transported sediments ; there is a more or less gradual increase in the percentage of amphiboles and tourmalines with increase in size ; zircon occurs upto a size of 0.25-0.35 mm. and disappears in coarser sizes ; percentage of garnet decreases with increase in size and disappears in grades coarser than 0.178 mm. ; and lastly epidote is more or less constant in amount in all size grades.

SOME IMPORTANT CONCLUSIONS

(1) Due to lengthy occurrence and presence of less resistant rocks (older and recent alluvium) towards the lower reaches, the river shows migrating courses and increase in sinuosity with horse-shoe bends near the mouth.

(2) The river first flows over the Archaeans and then over the Gondwanas. Contribution from both the terrains is well reflected in the transported sediments of the river but the pyroxenes are peculiarly absent in the transported sediments, although pyroxene-granulites are common in the Archaean source rocks.

(3) A gradual attainment of lognormality of the sediment size-distribution is seen from the source to the mouth of the river due to the gradual elimination of coarser fractions downstream.

(4) A decrease in the mean size with concurrent increase in sorting of the river

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sediments is noticeable from the headwater to the mouth of the river.

(5) A major negative size-roundness relationship of the river sediments is a reflection of the source rock control and this roundness is thought to be no measure of maturity of the sediments.

(6) Two deficient size grades one at 2-2.85 mm. (common for fluvial sediments) and the other at .088-.125 mm. (characteristic of Ajay) have been noted for sediments throughout the entire length of the river Ajay. The deficiency in the coarser grade is the result of instability of the composite grains and the deficiency in the finer grade is due to certain slower rates of settling velocity of particles in the range of suspension transportation as indicated from a negative linear size-roundness relationship (finer grains having better roundness settle faster) already reported in these sediments

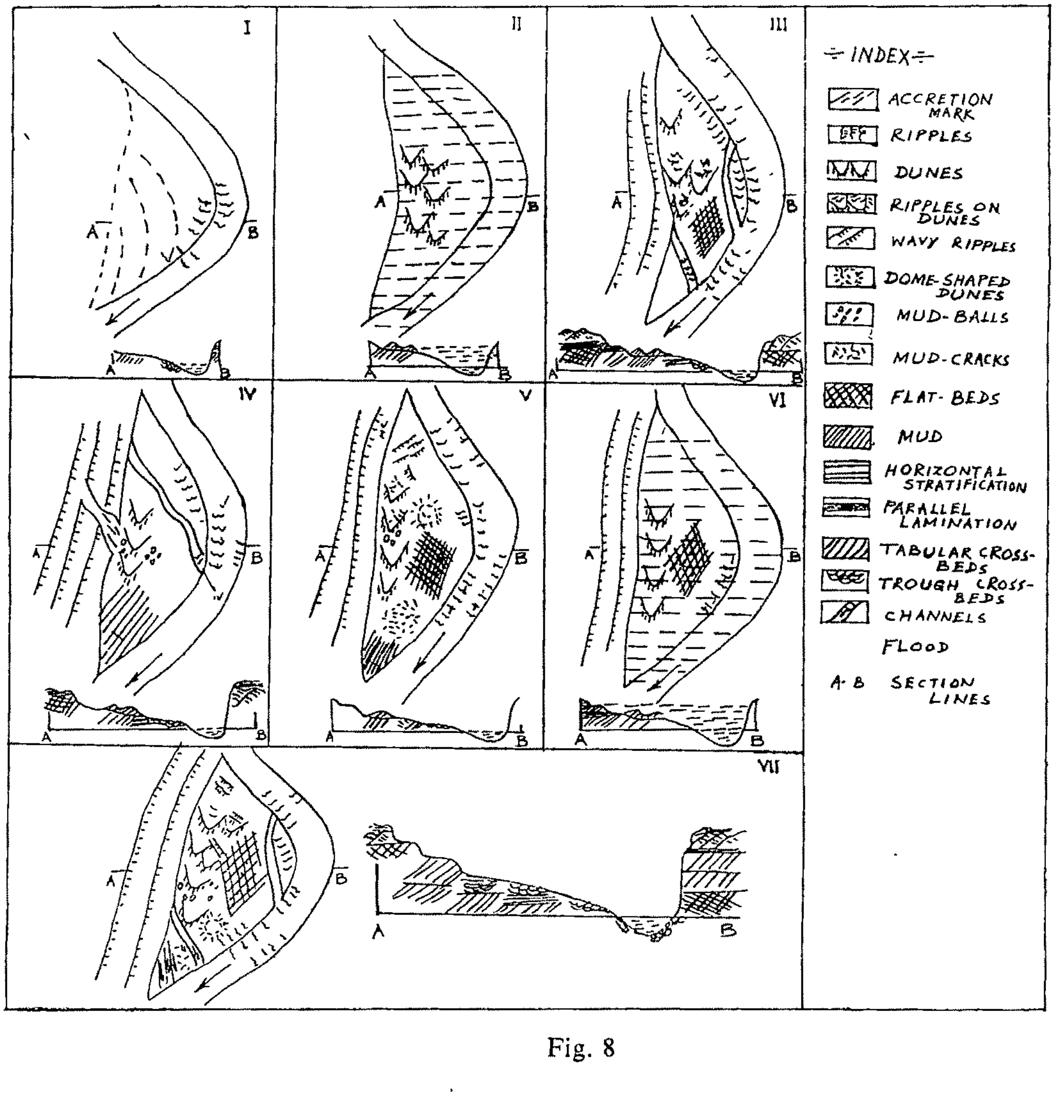

Fig. 8

(Bhattacharya, 1970).

(7) Two different mechanisms for the formations of sand (by abrasion) and silt (chipping) sized sediments have been confirmed from this study.

(8) Crescentic ripples and their corresponding smaller trough cross-stratifications have proved to be the best indicator of the current direction (Bhattacharya, 1969) for the unidirectionally flowing meandering rivers.

(9) A sequence of sedimentary structures (i. e., larger planar tabular cross-beds at the base through horizontal stratifications to small trough cross-beds at the top) representing high water to lower water stage (normal) of the river gives a complete cycle of fluvial sedimentation.

(10) There is a slight increase in the content of heavy minerals in the distributions from the source to the mouth of the river.

(11) A model for successive development of the sedimentary structures in meandering rivers has been suggested. (Fig. 8).

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EXPLANATION OF FIG 8

Model for interrelationship of sedimentary structures in a meandering river.

I) Normal flow condition—formation of point-bar by lateral accretion, ripples on channel and on the inner bank of the point-bar.

II) Flood—inundated—wider channel, point-bar covered, dunes form on the outer bank, flat-beds and pools.

III) During waning phase of flood—smaller channels form inside the bar with development of crescentic ripples, ripples superimposed on dunes, ripple drift lamination on the outer banks in areas of levee deposits.

IV) Late phase of flood—suspension mud deposition, small-scale graded beds, parallel lamination, groove-marks.

V) Period of non-deposition—wind action modifies the surface configuration a bit, aeolian ripples form, dome-shaped dunes form, armoured mud-balls, mudcracks, erosion of surface structure.

VI) Next catastrophic flood– earlier structures are covered by flood water, erosion upto a certain level, horizontal stratification dunes of next phase.

VII) General configuration of the sedimentary structures in plan and section representing a complete cycle of sedimention from low to high water stage of the river.

REFERENCES

Allen, J. R. L., (1963) : *Asymmetrical ripple marks and the origin of water laid cosets of cross-strata* : Liverpool & Manchester Geol. Jour. Vol. 3, p. 187-236.

Bhattacharya, A. K., (1969) : *Studies in the size-roundness relationship of fluvial sediment* : Science & Culture. Vol. 35, p. 31-35, Jany. 1969.

— (1969) : *Applicability of cross-beds in determining the (palaeo) current direction* : Q. J. Geol. Min. Met. Soc. India, Vol. 41, No. 1, p. 45-48.

— (1969) ; *Deformed cross-beds in the point-bar deposits of the river Ajay, West Bengal and Bihar* : Q. J. Geol. Min. Met. Soc. India, Vol. 41, No. 3, p. 169-171.

— (1970) : *Deficient size-classes of the Ajay river sediments, Bihar and West Bengal* (abs) : Proc. Ind. Sci. Cong. 57th Session, Part III, p. 191.

Boersma, J. R. (1967) : *Remarkable types of megacross-stratification.* Geol. Mijnbouw Vol.46, p.217-235.

Folk, R. L. and Ward, W.C., (1957) : *Brazos River bar : a study in the significance of grain size parameters* : Jour. Sed. Petro., Vol 27, p. 3-26.

Kolb, C. R., (1963) : *Sediments forming the bed and banks of lower Mississippi River and their effect of river migration* : Sedimentology, Vol. 2, p. 227-234.

Lane, E. W., (1938) : *Notes on the formation of sand* : Am. Geoph. Union Trans. Vol. 19, p. 505-508

Leopold, L.B., Wolman, M. G. & Miller, J. P., (1964) : *Fluvial processes in Geomorphology*, W. H. Freeman and Co., 522 p. San Francisco.

Moss. A. J., (1963) : *The physical nature of .common sandy and pebbly deposits.* Am. Jour. Sci., Part II, Vol. 261, p. 297-343.

Pettijohn, F. J., (1957) : *Sedimentary Rocks,* Harper and Bros. 718 p. New York,

Potter, P.E. & Pettijohn, F.J. (1963) : *Palaeocurrent and Basin Analysis,* Academic Press Inc. 296 p. New York.

Rogers. J.W., Krueger, W. C. & Krog, K., (1963) *Sizes of naturally abraded materials* : Jour. Sed. Petro. Vol. 33, No. 3, p, 628-633.

Simons, D.B. & Richardson, E.V., (1961) : *Forms of bed roughness in alluvial channels* : Am. Soc. Civil. Engs. Proc Vol. 87, No. HY 3, p. 87-105.

Simons, D.B , Richardson, E.V. & Nordin, C.F., (1965) : *Sedimentary structures generated by flow in alluvial channels*; Primary Sedimentary structure and their hydrogenetics interpretation, S.E.P.M. Sp. Pub. No. 12, p. 34-52.

Spencer, D.W., (1963) : *The interpretation of grain-size distribution curves of clastic sediments* : Jour. Sed Petro. Vol. 33, p. 180-190.

Sundborg, Ake. (1956) : *The river Klaralven : a study of fluvial processes* : Geog. Ann. Upsala Univ. Geog. Inst. No. 115.

Visher, G. S., (1965) : *Fluvial processes as interpreted from ancient and recent fluvial deposits* : Primary Sedimentary Structures and their hydrodynamic interpretation, S. E. P. M., Sp. Pub, No. 12, p. 116-132.

GENESIS, NATURE AND INTENSITY OF EROSION ON WESTERN RIMLAND OF MIDDLE KANGSABATI BASIN

PRANAB KUMAR RAY & SUNIL KUMAR MUNSI

Abstract

This paper gives a survey of the investigation on genesis, nature and intensity of erosion and related phenomena of western rimland in the middle Kangsabati Basin. The random stratified sample study reveals the relative balance of different erosional types and their respective intensities. The pedologic and phytogenetic aspects of this problem are related to the morphometric variables. Aforestation by itself is not adequate to tackle soil erosion in this area. Test of significance of the erosional types to morphometric variables brings out distinct relation between morphometry and erosional intensities. Sheet-rill association is the most destructive although gullying fosters illusory conservation practices. The propensity as well as current intensity of erosional types are enhanced in lower orders of morphometric status i.e. in the pied-plateau section. Sixteen soil erosion intensity associations have been brought out.

The alarming process of silting and consequent choking of the Bhagirathi-Hooghly has been the focus of many studies. It has been established beyond doubt that whatever might have been the role of the Ganga in the past, at present the contribution of the river to the total silt load of the Bhagirathi-Hooghly is next to nothing. By middle Tertiary times the South Bengal Basin was mainly getting sediments from the Eastern parts of the Peninsula. The Chotanagpur Plateau continued to rise during the Tertiary period with consequent sedimentation in the Bengal basin. In the Pleistocene times, the formation of the Garo-Rajmahal Gap completely changed the provenance status. But now with Bhagirathi having been cut off from the Ganga once again, the condition is reversed and the western rivers are playing the most important role in filling up the basin. The main contributors in this respect are the Ajoy, Mor, Damodar, Rupnarayan and Kangsabati.

It is, therefore, necessary to study the erosional processes on the basin rimland in minute detail. This paper gives a brief but pointed survey of the investigation on genesis, nature and intensity of erosion of western rimland in the middle Kangsabati Basin.

The river Kangsabati is the most southerly one among the tributaries flowing eastward from the western rimland of the basin. The area under study forms the rightbank rimland of the middle Kangsabati Basin. Its southern boundary is constituted by the Subarnarekha-Kangsabati watershed while to the north the river Kangsabati itself delineates it. To the east the rimland roughly coincides with the 100 m contour line. The area covers 341 sq. miles.

The geological frame work of this rightbank rimland is predominantly composed of gneisses and schists of Archaean formations. The Archaean rocks are mostly gneissose. Granites gradually become prominent towards the south-western corner of the area. But the predominance of gneissic rocks is obvious. The "Bankura Gneiss" has a foliated structure. The foliation of schists is mostly ENE-WSW.

As is usual with a shield-rimland, the area represents typical old age characteristics of low absolute altitude and moderately low relative relief. Absolute relief increases towards west marked by a line of sharp hills. Relief intensifies gradually towards west. It is below 25 ft. in the eastern rimland margin and rises to 350 ft. in the western section.

Intensity of erosion in a tropical humid area necessarily depends on intensity of rain, slope, its extent and steepness, the nature of soils and on vegetation cover. Drainage characteristics and dissection index reveal the interaction of the above factors and are an effective index of the nature and intensity of erosion. In this paper, therefore, we will briefly evaluate and associate them to the erosional types and intensities.

The rainfall and run-off data are inadequate and meagre. Silt-charge stations are few in number. No data regarding runoff intensity and rainfall intensity could be available. Any hydrological treatment of the salient features of the soil erosion is destined to be over-generalised.

Soils of the field area owe their origins to gneisses and laterites largely. The gneissic soils cover most of area to the west. Gneissic soils, formed on parent gneissic rocks, are susceptible to very intense erosion and gully formation. Lateritic soils are found mostly on undulating topography and are eminently suitable physiographically for runoff losses. Sandy loam patches are susceptible to ravine formation.

It has been estimated that in the last century, about 1000 square miles of land went out of cultivation due to erosion in four western districts of Bankura, Burdwan, Birbhum and Midnapur. In Bankura itself 10,787 acres out of her existing cultivable waste have been declared as eroded lands which need immediate reclamation. This rimland was once so thickly covered with forests that it used to be classified as 'Jungle Mahal' in the 18th century. The stratified random sample survey over this area reveals that in 1925 the percentage of area under forest was 59.86% in the higher western rimland. The corresponding figure for the lower eastern rimland was 21.6%. The area under forests diminished by 11%in 30 years and mean sample percentage decrease to 53.06% for higher western rimland. In 1970 the percentage of area under forest accounts for 49.34% and 8.92% of the higher and lower rimland respectively. The following table I shows the trend and intensity of deforestation as derived from the random sample survey.

Table 1

Percentage of total Area under Forest

	1922	1955	1970
Higher Western Rimland			
Forest	59.86	53.06	49.34
Plateau Eastern Rimland			
Forest	21.6	18.24	8.92

The devastating rate of deforestation reached its peak from the early part of the present century. Much of the marginal lands were hastily transferred to fallow wastelands after the initiation of W. B. Estate Acquisition Act of 1953, after which forests were finally acquired. But improvement was marginal. The sample mean values indicate the relatively rapid rate of deforestation in the lower eastern rimland.

The pedologic and phytogenetic features are not clear enough to suggest the salient nature of the erosional morphology. The characteristics of drainage, slope morphology and dissection are worked out in detail to get the minute picture of the erosional genetics.

In the south-western part of the study area drainage density is moderately coarse (6 miles/sq. mile). This is again the region of moderately high dissection index (.32): Percentage density frequency of the first order streams denotes the coarseness of the texture and the predominance of gullying over sheet wash. Moderately fine drainage density (2-4 miles/sq. mile) group covers 58% of the study area. Percentage density frequency of 3rd order streams ranks high in this zone. Very fine (below 2 miles/sq. mile) drainage density zone flanks the eastern rimland.

The absolute values of dissection index for the study area vary from 0.05 to 0.45. Moderately high dissection values cover only 4.7% of the study area while moderate dissection index covers 69% of the study area. The area of low dissection value is concentrated on the eastern fringe rimland. But these areas have low drainage density.

To find out the average slope of the field area Wentworth's method was followed and the size of grid unit selected was 0.25 sq. mile. The slope values vary from 0.25° to 6°. Moderately steep slope (4.5°-6°) is frequent on the higher western rimland covering 29% of the study area, while moderate slope value (2°-4.5°) covers the greater part of the lower eastern rimland.

The findings of these morphometric values (slope, relief, dissection index, drainage density. percentage drainage frequency) are analysed to indicate the nature of erosional genetics. To estimate the relative balance of various types, their respective intensities and their morphometric association, random samples were taken from the morphometrically differentiated regions/strata viz, (i) higher western rimland (ii) lower eastern rimland. Altogether 60 samples were taken from the two strata; taking 24 from the higher western rimland and 36 from the lower eastern rimland. The relative balance of the various erosional types, viz. sheet, rill, gully and ravine, was computed. From the sample units of stratum I (higher western rimland) the following sample means were obtained.

Table 2

Percentage of Area

Higher Western Rimland				
Inwash	Heavy Sheet	Sheet/Gully	Light Splash	Confused
3.7	12.3	26.3	54.5	3.2
Lower Eastern Rimland				
Inwash	Heavy Sheet	Rills/Sheet	Rills Heavy/Light sheet	Confused
3.06	27.25	53.72	1.5	14.47

The areal share of various erosional types are calculated

The spatial variations in the relative balance of different erosional types in the two strata are revealed in the sample mean values. In the discussion of erosional characteristics some objective assessment of the validity of difference between several sets of variables is 'significant' or not.

Sample values suggest a marked increase in the percentage of area under heavy sheet erosion when the regional slope is below 1.5°. Chi-Square Test for these sheet erosion values reveals that the relevant probability value is less than 10%, which suggests at least 'probably significant' variance.

Snedecor's F Test was applied to estimate the significance of difference of sample values under rills/sheet type. One likely factor leading to such difference was assumed to be altitude at which the samples lie. But the F values (required at 1% level—6.1, .5% level 3.6 observed F 2.63) indicate a chance occurrence and absolute altitude alone can not signify occurrence of rills/sheet infested lands.

F test for the distribution of light sheet/splash infested lands in different altitudinal ranges reveals that the observed F values have a tendency to occur near less than 1% probability level which means that variance in percentage holding under sheet/splash type have 99% chance to be moderated by altitudes.

Chi-Square test of samples with percentage holding under in-wash to percentage density frequency indicates a x^2 value of .91 against 2° degrees of freedom and this shows the highly significant difference between different percentage density frequency values.

Tests of significance of these various erosional types to different morphometric elements were added with correlation diagrams and co-ordinate models and sixteen Soil Erosion Intensity Associations have been brought out as listed in Table 3.

The preceding text denotes that each erosional type has certain morphometric indicator. These indicators are not identical for the various erosional types but a common factor is not far from the rule. The morphometric character of a stratum determines and strictly controls the various soil erosion intensity indexes. Thus, the gross spatial extension of any

Table 3

Morphometric status	Soil Erosion Intensity Association.
1. H C H RR DD DI	L ModH VHigh Sh Ri Gu
2. ModH CF RR DD	ModL High VLow Sh Ri IW
3. Mod Mod C RR AA DD	H L ModL IW Sh Gu
4. L C RR DD	H VH Gu Ri
5. Mod ModF L DI DD CF	ModL L Sh Ri
6. L VF VL L RR DD CF DI	ModH Sh
7. F H St L DD DI S PDF	VL H L IW SP Sh
8. Mod St H H S DD DI	VL H ModH Sh Gu Ri
9. ModH St ModF AA S DD	VH L Ri, Sh Gu
10. Mod G L S DI	ModL L VL Sh Ri IW
11. Mod G ModL H S DI PDF	H ModH Sh Ri
12. G VL S DI	VH L Sh, Ri Gu
13. H L F AA DI DD	L ModH Sh Ri
14. H G RR S	ModH Mod Ri Sp
15. MH L A Ar	H ModH VL Sp Ri Sh
16. St Tors S	VH H H Gu Sh Sp

Abbreviations

AA - Absolute Altitude, St - Steep, Sh - Sheet, RR - Relative Relief, C - Coarse, Ri - Rill, DI - Dissection Index, F - Fine, IW - Inwash, VF - Very Fine, DD - Drainage Density, H - High, Gu - Gully, L - Low, S - Slope, Mod - Moderate, SP - Splash, VL - Very Low, PDF - Percentage Drainae Frequency, Ar - Percentage of arable land.

erosional category is directly regulated and predefined by the morphometric combinations.

Deforestation undoubtedly accentuates erosion. But deforestation alone is not the prime factor. The sample survey has revealed that intensity of erosion is much greater in the fallow marginal lands and the rate of increase of 'marginal land' does not absolutely depend on the havoc of deforestation. Hence aforestation itself does not come out as the only solution of these erosional problems. The steady culture of the 'marginal lands' is the most required necessity. This must, of course, be added with evaluated optimum aforestation.

The intensity of sheet-rill erosional association is higher than the ravine-gully intensity association. The ravines themselves expose depositional elements which are more conspicuous than the rate and degree of loss they inflict. The spatial coverage of the sheet-rill association is three times greater than the latter association.* The propensity of erosion is more intense in the lower order of morphometric status. The higher the morphometric status the lower the intensity of sheet-rill association. But the lightly splashed areas increase with higher morphometric status. The percentage of area under forest also increases with increasing morphometric order. The most potent zone of intense stripping is the pied-plateau, transition between the higher western and lower eastern rimland. This is the only zone where heavy sheet-rill is associated with moderate gullying and -intense ravine morphometry.

Through a detailed and complex morphometric soil erosion intensity evaluation it is possible to evolve a rational soil conservation policy. Such an evaluation would expose the illusion that only checking of gully erosion can solve the problem of soil erosion in a rimland zone as the one taken for study in this paper.

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* Report on land capabilities Survey in Purulia and Bankura District, 1968. Department of Land Use Extension Bureau.

TECTONIC LANDFORMS OF THE SOUTH-WESTERN FRINGE AREA OF THE BHAGIRATHI-HOOGHLY BASIN

S. C. MUKHOPADHYAY

Abstract

The paper deals with some aspects of tectonic landforms of the south western fringe area of the Bhagirathi-Hooghly Basin. The present configuration in general and the characteristics of rivers like the Subarnarekha and Kaliaghai in particular, have a great bearing on the occurrence of floods affecting the entire economy of a part of the Bhagirathi-Hooghly Basin.

Fluvial interruptions in this unstable zone have brought about notable riverine features, thus correlating the evidences of tectonic control on the shifting of the river channels of the area. In the western segment the landscape is very striking with characteristic undulating downs, meandering streams with shifting shoals, river terraces and other river-traces developed in part of this elevated western plain (Chotanagpur plateau) representing an old planation surface. It seems possible that the uplift of certain areas along the western part of the Bhagirathi hinge belt was repeated in recent time with the result that the upper reaches of drainage systems like the Bhagirathi, the Haldi, the Subarnarekha etc. are found to be incised with a tendency to shift further east from their present course.

The paper deals with some aspects of tectonic landforms of the south-western fringe area of the Bhagirathi-Hooghly Basin which covers most of the districts of Midnapore, Howrah, Hooghly, Purulia, Bankura, 24 Parganas of West Bengal, parts of Singhbhum District (Bihar) and Balasore (Orissa). The area with its varied riverine features is formed between the undulating and broken land surface of a part of Chotanagpur table land and the great Brahmaputra-Ganga delta, and is criss-crossed by numerous rivers big and small with meander scars, valley fills and creeks etc. which illustrate its multiple origin.

In order to study the current tectonic landforms of the area it is essential to consider the underlying geological structure, the processes involved in fashioning the surface and the stage reached in the present and in earlier cycles of erosion. The key to this study lies primarily in the recognition of the relationship of tectonic landforms with the drainage systems of the Bhagirathi-Hooghly group and the

Subarnarekha River etc. to the south western fringe area of the same basin they drain.

The structure of the thick cover of Ganga alluvium of this part of the basin which has concealed the tectonic history of the extensive Tertiary deposits, is comparatively simple. Here, the Tertiary beds dip south-eastward (homoclinal dip) at about 2 degrees and are crossed by a number of normal faults and faultline scarps trending NNE-SSW and by some other faults aligned in different directions. The pattern has some resemblance to the fault pattern of the Foreland Spur but with fewer faults, and these have been developed along the eastern margin of the shallow basement ridges. It is characterised by a series of subsurface basement ridges in the neighbourhood regions of the eastern part of the pre-Cambrian shield area. The basement is found at comparatively shallow depths throughout the western part of the alluvial area, but the Tertiary beds thicken to the south-east as they pass from the shelf facies to the geosynclinal facies, and the basement must be at very great depth in the eastern part of the region i.e. the Surma Valley (about 13,000 m.). It has been found that there is good evidence of pronounced facies changes in the Eocene (from the Sylhet Limestone of the stable shelf to a dominantly clay stone and shale section eastward) and in the younger Tertiary Section (from arenaceous sediments of the stable shelf to a dominantly argillaceous section in the east). Therefore, the depositional environment of Bengal basin changed sharply from stable shelf to deeper-basin conditions, along a zone between the Hooghly River and the Calcutta-Ranaghat line. The area east of this hinge zone, with its great thickness (exceeding 900 m.) of predominantly clay stone and shale facies, possibly is the mobile shelf (miogeosyncline of some authors) of the Bengal basin.

It has already been referred that the eastern margins of the buried basement ridges in many places plunge steeply toward the east, suggesting the presence of a series of normal faults, some of which are modified by fault line scarps by erosion (Sengupta, 1966). Areally, these faults are arranged in an *en echelon* pattern and they might be the shallower expressions of some major basement structure along the western fringe of the Bengal basin. Further, seismic evidence suggests that at least some of these marginal faults of the basin were active contemporaniously with sedimentation. Sengupta (1966) argues, it is possible that this structural zone along the basin margin behaved as a *tectonic hinge* and controlled, to some extent, the depositional conditions of the basin throughout the Tertiary. Again outpouring of basalt flows (contemporary to Rajmahal area on the foreland shelf of Bengal occurred probably in Late Jurassic and Early Cretaceous time.

During late Cretaceous, the out-pouring of basalt flows, was followed by a slow subsidence of the Bengal shelf area and marine invasion from the southeast. Repeated submergence and emergence must have taken place in the shelf area during Late Cretaceous to middle Eocene time and in most of the shallow shelf regions freshwater sedimentation of sandstone and carbonaceous shale continued. Basin-wide subsidence, presumably initiated by the movements in the basin margin fault zone, caused extensive marine transgression in middle to late Eocene time. Nummulitic limestone was deposited uniformly under open-marine warm conditions over the entire shelf area of Bengal (and the south Shillong Plateau).

Movements seem to have begun during Eocene time, on a second major hinge belt, the so called "Sylhet Limestone hinge", which trends in a N. Ely direction below Calcutta and transverses the whole of Bengal and Assam basins. This *flexure* on the Eocene limestone is probably a shallower expression of a deep-seated structural feature in the basement. During Miocene time, practically all of Bengal and Assam was subjected to major *tectonic movements.* In West Bengal, the area east of the Memari-Ghatal trend was transgressed by the sea, and deposition of the dominantly argillaceous Miocene sediments (middle part of the Bhagirathi group) resulted. On the stable Bengal shelf deposition under oscillating, deltaic, and shallow marine conditions continued.

TECTONIC LANDFORMS OF THE SWn FRINGE AREA OF BHAGIRATHI-HOOGHLY BASIN

With the regression of the sea during late Miocene and early Pliocene times, e.g. movements on the Dauki fault, Naga thrust etc., estuarine and fluviatile conditions of deposition prevailed in most of West Bengal. Only very small scale, local marine transgressions followed this large scale Pliocene regression in some parts of Bengal. During early Pleistocene time, shallow-marine conditions prevailed only, in the deeper parts of the Bengal basin. Possibly only very late in the Pleistocene did the sea finally recede completely from the Bengal basin area. Erosion then occurred, followed by peneplanation of the whole Tertiary basin area of Bengal. Finally, the older sediments were covered completely by a thick mantle of river-borne Holocene alluvium. Frequent recent earthquakes in the orogenic belts of the eastern Himalayas and the Naga-Lushai Hills (although situated beyond the studied area) suggest, however, that movements are continuing in the basin and that the folded belts have not yet attained equilibrium.

In some of the seismic profiles good evidence of *erosional scraping* is noticed in this zone e.g. in the Bolpur, Galsi, West Ghatal etc. and in some other adjacent sections strong evidence of *normal faulting* exists. It is possible that, locally, these normal faults at the basin-fringe are modified by erosion to *fault line scarps* (Sengupta 1966). It should be referred that most of these basin-margin faults have affected the basalt trap unit (Rajmahal Group) and also some of the young Tertiary sections. Extent of the faults into the very shallow sections of this part of West Bengal is, however, only conjectural, because the correlation of the sporadic and non-persistent reflections of this zone is doubtful in many places. Faulting probably has occurred at different times during the accumulations of the huge thickness of Tertiary sediments of West Bengal. Correlation of reflectors across many of the faults in the basin-fringe areas indicates appreciable, abrupt increase of thickness of individual sedimentary units from the upthrow to the down throw sides of the faults, suggesting that at least some of these faults were contemporaneous with sedimentation (Sengupta 1966). However, on the basis of gravity surveys (Bouguer gravity map) it is possible to infer that a *zone of marginal faults and fault-line-scraps* borders the whole western and south western fringe of the Bengal basin. The zone of the *en echelon* faults near the basin margin might throw some light on the *tectonic history of the basin.*

In some places, these faults are believed to be the surface expression of *deep-seated shearing movements* in the basement. It might be envisaged, therefore, that the basin-rim *en echelon* fault zone in the Tertiary section of West Bengal, is at least to some extent, the shallower expression of more deep-seated, major movements—similar to the Singhbhum shear zones—in the basement. It is also possible that this zone of scraps and faults which developed contemporaneously with Tertiary sedimentation, but presumably caused by deeper fractures in the basement, has *played a major role in the later tectonic and depositional history of the basin by acting as a tectonic hinge zone.*

According to some interpretations, the increase in time-dip of the "D" reflector east of Memari continuing to the Hooghly River, is the result of a velocity anomaly in the shallower section ; if proper corrections are made for this velocity anomaly, the spurious dips on the Sylhet Limestone surface should disappear and the structural contours on this surface should indicate a *uniform gradient* for the whole area west of Calcutta. Seismic indications of unconformity in the form of a change in dip between the Pliocene and Miocene (middle part of Bhagirathi group) sections are noted practically throughout the shelf area. This fact, together with the presence of conglomerate beds at the base of the Pliocene in some of the wells, suggests the presence of a stratigraphic break at the top of the Miocene. It should be noted that no discordance of dip was observable in the core samples from the zones above and below the proposed unconformity (Biswas, 1963).

In the area a series of low order magnetic "highs" occur northwest of Calcutta. Moreover, a relatively steep gravity gradient west of Calcutta is flanked on the east by a series of broad gavity "highs". These gravity- magnetic trends suggest a sharp drop in basement topography below the hinge belt postulated from seismic interpretation. This hinge belt, as mentioned above, noted in a relatively small part of West Bengal, is actually a feature of regional importance and must have played a major role in the tectonic and depositional history of the Bengal basin. Here, a change in lithofacies would be anticipated to occur in the hinge zone that separates the stable shelf from the relatively rapidly subsiding geosynclinal trough. It appears that the rocks of these two different facies originally were deposited close to each other.

Towards the end of the Tertiary period, eastern Dhalbhum formed part of the coast along the Bay of Bengal, a coast line along which rugged hills rose over a thousand feet abve the surrounding plains. Whilst sediments were being deposited here, under perhaps estuarine conditions, differential uplift took place inland ; the resultant rejuvenation gave rise to plains at a lower level, leaving small isolated plateaux as evidence of the old planation surface (peneplain). A further general uplift subjected Tertiary grits to stream erosion. But with decreasing gradient in its lower reaches, the Subarnarekha and other east-flowing rivers are now building up their own flood plains. Thus, the works of sedimentation and coalescence of the alluvial fans of the basin occurred under different enviromental conditions during successive stages marked by large scale marine regressions, local tran gressions and epeirogenic uplift of the basement.

In recent years it has been found by geologists that the mode of sedimentation was initially marine and estuarine along with deltaic and fluviatile in its later developments[1].

LANDFORM CHARACTERISTICS

Morphologically the SWn fringe area of Bhagirathi-Hooghly basin exhibits most varied topographic-forms and is characterized by two sharply contrasted regions from west to eastern side of the basin. Studies of the configuration of the area shows undulating and broken land surface marked by a number of projected spurs along with low laterite swelling ridges on the west, and plain flat surface on the east and south where sand hills and marine terraces of varying breadth spread out along the coast of the Bay of Bengal. Towards the bay these ranges (15m. in average, a.s.l.) generally slope (10°—25°) gradually into the coastal alluvial plains.

Therefore, from the western part, undulations continue towards the east till they give place to plain flat surface where the poly-profilic laterite base lies in places covered up by alluvial deposition. The distant low ranges of the western part of Chotanagpur plateau, where dense growth of Sal trees (*Shorea robusta*) cover the ridges with red soil, present a picturesque landscape to the western part of the basin.

LATERITE HILLS

Here, the surface laterite has apparently formed from gravels and gravelly sands of probable Pliocene age. Thin patches of the Pleistocene upland clay are locally present on this laterite which are observed in the Kasai Valley around Kharagpur area The laterite belt is a south-westerly extension of the "Bankura laterite" (as low-level laterite of Pascoe, 1964). Local occurrences of a lateritic conglomerate is noticed and experts are of the opinion that all these laterites represent palaeosoils that originated through *in situ* lateritisation of a variety of materials as Pre-Cambrian rocks like granite, Khondalite, dolerite etc., Rajmahal Traps, Miocene and Pliocene rocks. Niyogi (1968) describes the typical lateritic soil profile as a hardcap (1 to 10 m. thick) at the top, grading down to a mottled brown and grey clay (3 to 20 m.) ; this clay gives way, through a bleached zone (2 to

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1. Most of the information regarding the geology of the area have been compiled from Sengupta (1966).

5 m.) to the parent material which may be either rock or unconsolidated material. The entire profile is, however, rarely visible at one place, and a varied truncation of the profile has exposed different horizons at different places. The hardcap has given rise to a mildly rugged rock-like terrain. Surface expression of the mottled clay is a gently undulating plain which may be referred to as the lateritic plain. In the upper reaches of the Kaliaghai river, the poly-profilic laterite which shows a double profile has been noticed. The upper profile is Plio-Pleistocene in age, while the lower profile is somewhat older (Niyogi, 1970). In some places disconnected patches of an upland clay (Pleistocene) are found above the laterite while the main occurrence of the Pleistocene lies east and south-east of the laterite fringe. The Pleistocene formation has given rise to a relatively smooth plain sloping towards the mouth of the Hooghly River (the Ganga System). Undulating lands with isolated peaks within the low laterite swelling ridges are found here and there till flat plains appear.

SANDY RIDGES

Thus rolling down continues towards the east, undulating surface gives place to plain flat surface of alluvial deposition. In south, near the Contai coastal plain, sand hills spread out almost parallel to the coast, and starting from the Rasulpur river, these hill ranges proceed westward about 10 km. off the coast and extend further southward in Orissa, beyond the studied area. Three distinct lines of sandy ridges are generally present along the seaward side of the basin and it exhibits the features of morphogenetic control of the marine processes in association with the tectonic movements. These ridges are intervened mainly by swales, inlets and river mouths and these are invariably wider near the river mouth where the average width is about 100 m. Away from the mouth the ridges gradually become narrower.

The north faces of these ranges mostly appear like walls (with 65° and more slopes which attain a height of 18 m. at some places) while the south faces generally slope down gradually (8° to 16°) into the coastal alluvial plains. Coastal dune sands occur along all parts of the coast in varying width in a pronounced west-south-west to east-north-east direction and seems to have been guided by the ocean current in association with the south-west monsoon wind. These beach ridges are composed of materials that are believed to have been piled upon the backshore by storm waves, and they generally conform to the present or ancient shoreline configurations. Here, the main constituent of the beach ridges is medium to fine sand. Niyogi (1970) believes that these ridges which are at present 4 m. high in average ; were initially somewhat higher ; subaerial erosion subsequent to the shift of the shore line had its effects. Beach ridges are often activated by the wind and may thereby get modified into dune ridges which may be considerably higher e.g. 10-12 m. a.s.l. Towards the Subarnarekha estuary area a complicated array of five belts of beach ridges has been noted.

An almost continuous line of dune ridges has developed along the present shore line. This coastal line of dunes was previously quite wide, and in spite of steady erosion on the seaward side, the width of the dune belt was steadily maintained due to landward migration of the dunes. Even in 1948, the dune belt was on an average 200 m. wide. Afforestation (casurina trees) of the dunes around 1950 halted the landward march of the dunes while the seaward erosion has continued as a result of which the coastal dune ridge has become very narrow with an average width of about 75 m. The seaward face of the dune ridge, which forms the present coast line, is straight, but the landward margin is serrated due to differential march of the dunes, e.g. hair-pin dunes (Niyogi 1970). To the south of Contai five separate dune ridges occur like the coastal dune ridge, a short barrier bar just to the north of it, a long dune ridge along the barrier bar, and the other beach/dune ridges etc. The older dune ridges are marked by more severe erosion, and at many places blow-outs have been formed by erosion of dune ridges. Further, these are characterised by the nearly uniform orientation of the notch-shaped hair-pin dunes forming along all the dune ridges.

It should be noted that the sandy ridges as described above are located on a series of sandy-silty marine terraces, formed by the combined effects of both marine and fluvial agencies being aided by the uplift of the land relative to the sea. Oldham believes that each range of sandhills marks an old sea coast, and it seems probable that the sea has retired, that is, the land has been elevated not continuously, and uniformly, but at intervals, and by interrupted lifts. The present author likes to stress on the concept of tectonic control in the evolution of the sandy marine terraces along the coastal region of the area.

DRAINAGE SYSTEMS

The area is drained by a number of streams, the Rupnarayan, the Kasai, the Kaliaghai, the Haldi, the Rasulpur (The Bhagirathi-Hooghly System) and the Subarnarekha, etc. The drainage patterns show an north-west—south-east zonation in accordance with the general south-easterly slope which seems to be influenced by the underlying geological structure of the basin. Apparently, except the Kaliaghai River, a tributary to the Haldi River, most of the rivers (The Hooghly System) of the area bounded by the 10 m. and 50 m. contours, make their way in a general west to east direction with a notable change of their course towards south-east below the 10m. contour line. Locally the area is characterized by an almost rectangular drainage pattern. The Hooghly is the main channel for drainage.

The Kasai (the Kangsabati) flows through the area in a crooked manner, meandering over the northern part of Midnapore plain and falls into the Haldi river and then the Hooghly river. Actually the Haldi river is formed by the confluence of the Kaliaghai and the Kasai river (22°09′, 87°50′). All these rivers are characterized by traces of meanderscar, cut off, and terraces etc, and bear shifting shoals. The Rupnarayan, the Damodar, the Silai (Silabati), the Kasai, the Rasulpur, the Haldi rivers with their tributaries, offshoots, feeder channels and canals, etc., merge with the Hooghly river, the main channel for drainage, and form an effective drainage system of this part of the basin. Most of the rivers are subject to tidal bores. The drainage of the extreme western portion of the studied area is caught by the Subarnarekha river.

It should be noted that in the region of the Kaliaghai Basin flood and drainage problems are very important. The Kaliaghai in recent times has reached a moribund condition and its bed appears to have attained a greater altitude than the surrounding country. It rises out in Kalsibhanga (85 metres, 22°20′, 87°06′) and rushes across Jhargram Police Station in a south-easterly direction. It receives the stream Bhogi, north of Pataspur Police Station. On its journey further down-stream, it is reinforced by the Kapaleswari stream near Sabang Police Station. Ultimately it meets the Kasai at the trijunction of Moyna, Bhagabanpur and Mahisadal Police Stations. As mentioned above, the Kaliaghai causes floods and is well known for its erosive power (during S.W. monsoon period), specially in its upper reaches. The present surface configuration (besides concentrated rains) of the basin plays an important role in causing disastrous floods. Here, floods result whenever the channel capacity is exceeded by the run off. Excessive run off or rainfall is the fundamental cause, but in this area the channel capacity of the Kaliaghai has been affected by reduced gradient, siltation of the stream bed and also, by sudden changes of direction, past the 10 metre contour (from almost N-S to E-W). It should be referred in this context, that the excess of water supplied by the Subarnarekha river from west and lack of normal drainage of the channel due to the saturated condition of the Kasai River in its lower reaches during the S.W. monsoon period, cause damage to the drainage condition of the Kaliaghai and floods occur. In the rainy season, long continued rains charge the soil to its full capacity and the proportion which runs off becomes progressively greater.

The floods in the Kaliaghai Basin especially in Pataspur, Bhagabanpur area, not only cause damage to the standing crops and human habitations, but also take a heavy toll in terms of human and animal life. The floods also cause soil erosion in the upper reaches of the tributaries e.g. in Jhargram area. This type of erosion is of greater intensity in the upper reaches of the delta than in the lower reaches of the river. The velocity of flood water is also one of the factors that contributes substantially to the soil erosion, e.g. streams with a velocity of 1/6 mile per hour will barely move fine clay ; with a velocity of 1/4 mile per hour it will move fine sand ; with 1½ miles per hour it will transport pebbles of about 3 cm. diameter.

The Government of West Bengal have taken measures to combat floods of the region since the year 1969.

CONCLUSION

From an overall assessment of present surface features and of the processes actively fashioning the landscape of the south-western fringe area of the Bhagirathi-Hooghly Basin it would appear that the concept of tectonic control repeated in recent times offers the best interpretation of the conditions in this region. Fluvial interruptions in this unstable zone have brought about many notable features thus correlating the evidences of tectonic control on the shifting of the river channel of the area. In the western segment, the landscape is very striking with characteristic undulating downs, meandering streams with shifting shoals. river terraces and other river traces developed in parts of this elevated western plain representing an old planation surface. That the present day configuration, and the alignment of the river courses of the alluvial area of the Bhagirathi-Hooghly basin was due to gradual change of basin axis from east-south-east to south-south-east and tilting during comparatively recent times, was referred to by some of the scientists who worked in this region (Sengupta, 1966, 1970 and Biswas, 1964 etc.).

The antecedent character of the Subarnarekha river while passing through the Dalma lava country and in the Singhbhum district (Bihar) cannot go unnoticed. Midnapore district (West Bengal) bears another evidence of uplift of the western segment. The occurrence of earth tremors, though of mild intensity in the neighbourhood region of the basin especially in eastern Singhbhum and western Midnapore district, also suggest of the unstable nature of the western part of the basin. The idea of gradual south-easterly tilt of the basin also finds support in the past records of the changing courses of the rivers e.g. the Bhagirathi, the Hooghly, the Damodar etc. Now, geologists are in favour of the hypothesis of migration of the main courses of the rivers in a southerly direction in near future. The tectonic control of base level consistent with rejuvenation of the drainage by repeated earth-movements in recent times cannot be denied. It seems possible that the unequal uplift of certain areas along the western part of the Bhagirathi hinge belt was repeated in recent times with the result that the upper reaches of drainage systems of the Hooghly and the Subarnarekha rivers are found to be incised with a tendency to shift further east or south-east from their present course.

REFERENCES

Bagchi, K (1944) : *The Ganges Delta,* University of Calcutta. 157 p. Calcutta.

Biswas, B (1963) : *Results of exploration for petroleum in the western part of the Bengal Basin, India,* Proc. of the 2nd Symp. Dev. Petrol. Res. ECAFE. Min. Res. Dev. Ser., No. 18. Pt. 1. p. 240-250.

Morgan, and McIntire (1959) : *Quaternary Geology of the Bengal Basin, East Pakistan and India,* Bull, Geol. Soc Amer, vol. 70.

Mukhopadhyay, S. C. (1968) : *Erosion surfaces in the Sanjai River Valley, The Subarnarekha System, Bihar.* I.G U., S-25, Ranchi University.

Niyogi D (1967) : *A preliminary note on the morphology of the eastern shoreline of India.* Proc. of the Seminar on Geomorphological studies in India, Saugar.

Russell, R. J. (1963) : *Duration of the Quaternary and its subdivisions.* Proc. of the Nat. Acad. Sci. (U.S.A.). vol. 52.

Sengupta, S (1966) : *Geological and geophysical studies in western part of Bengal Basin, India,* Bull. Amer. Assoc of Petrol Geologists. vol. 50 pp. 1001-1017.

A STUDY OF EXTREME ONE-DAY POINT RAINFALL OVER BHAGIRATHI-HOOGHLY BASIN

O. N. DHAR, P. P. KAMTE AND A. K. KULKARNI

Abstract

In this study probable maximum rainfall (PMP) has been worked out for about 93 stations in and around Bhagirathi-Hooghly basin using the latest technique of Hershfield. Only those stations in this region have been selected for this study whose daily rainfall data are continuously available for the 60 to 70 years from 1891. Using Gumbel-Chow method, maximum one-day rainfall for the 93 stations for return periods of 2, 5, 10, 25, 50 and 100 years have also been worked out and generalised charts prepared. Nomogram for obtaining maximum rainfall for intermediate return periods from 2 and 100-year generalised charts has also been prepared. Analysis of maximum rainfall of shorter durations (durations less than 24 hours) for one self-recording rainfall station (viz. Calcutta) whose data are continuously available since 1948 has also been carried out and the results presented.

A knowledge of maximum rainfall distribution over a basin is essential for the proper planning and design of hydraulic structures. In situations where no risks can be undertaken due to failure of such structures the design is based upon the extreme rainfall that a basin is likely to experience. This estimate of extreme rainfall has in recent years come to be known as probable maximum precipitation (hereafter referred as PMP). It is defined as that magnitude of storm rainfall which should not be exceeded over a problem basin or an area during a given duration.

In this paper the following rainfall studies have been carried out for an area bounded by Long 86° to 89°E and Lat. 22° to 26°N :

(a) Preparation of generalised chart of one-day PMP over this region.

(b) Estimation of maximum one-day rainfall for different return periods of 2, 5, 10, 25 and 100 years.

(c) Study of point rainfall distribution of a representative self-recording rainfall station within this area.

The above area of study comprises of the entire Bhagirathi-Hooghly basin and its surroundings. This area is also known as the lower Ganga valley. About 93 stations in this area, whose daily rainfall data are continuously available for the last 60 to 70 years from 1891, have been considered for the above studies.

ESTIMATION OF PROBABLE MAXIMUM PRECIPITATION (PMP)

In this paper Hershfield technique (1961, 1965) has been used for the preparation of a generalised chart of PMP. Preliminary appraisal of this method in USA (Myers, 1967) and Canada (Bruce and Clark, 1966) has shown that the results obtained by this method are fairly comparable with the results obtained by the conventional storm analysis approach. WMO Guide to Hydromet. practices (1965) has also recommended this method for obtaining tentative estimates of extreme rainfall for small basins where daily rainfall at individual stations are available for a long period of time but data for storm maximization are lacking.

Table-1 gives the number of stations used in this study in the three contiguous states of West Bengal, Bihar and Orissa together with their respective periods of rainfall data.

Hershfield Technique

Hershfield (1961) technique is based upon the assumption that the information regarding the extreme rainfall at a station is contained in the long rainfall records of that station.

Hershfield used Chow's general formula for frequency analysis in developing his technique. In Chow's (1951) general formula

$$X_T = \bar{X} + \sigma . K_T \quad \dots \text{(I)}$$

where X_T, the extreme phenomenon, is a function of the mean ($\bar{X}$), the standard deviation (σ) of the extreme annual series and the frequency factor K_T. According to Chow (1953), the frequency factor K_T depends upon the return period T and its value for the extreme value distribution is given by the following equation :

TABLE 1

Statewise distribution of stations over Bhagirathi-Hooghly area with long periods of daily rainfall data from 1891.

Length of rainfall record (Years)	Number of stations used in this study			Remarks
	West Bengal	Bihar	Orissa	
70	7	18	1	Total number of stations used =93.
69	5	5		
68	8	2		
67	8	6		
66	5	3		
65	1	2		
64	4	1		
63	2	2		
62	1	—		
61	2	1		
60	4	2	3	
Total	47	42	4	

These conversion factors are almost identical with these obtained in USA (Hershfild and Wilson, 1957) and other countries of the world.

ANALYSIS OF SHORT DURATION RAINFALL FOR A REPRESENTATIVE SELF-RECORDING RAINFALL STATION

In the preceeding sections an attempt has been made to estimate maximum one-day rainfall for individual stations in the Bhagirathi-Hooghly region. An attempt has been made in this section to study maximum rainfall for shorter durations of 1, 2, 3—24 hours for a representative self-recording station in this region.

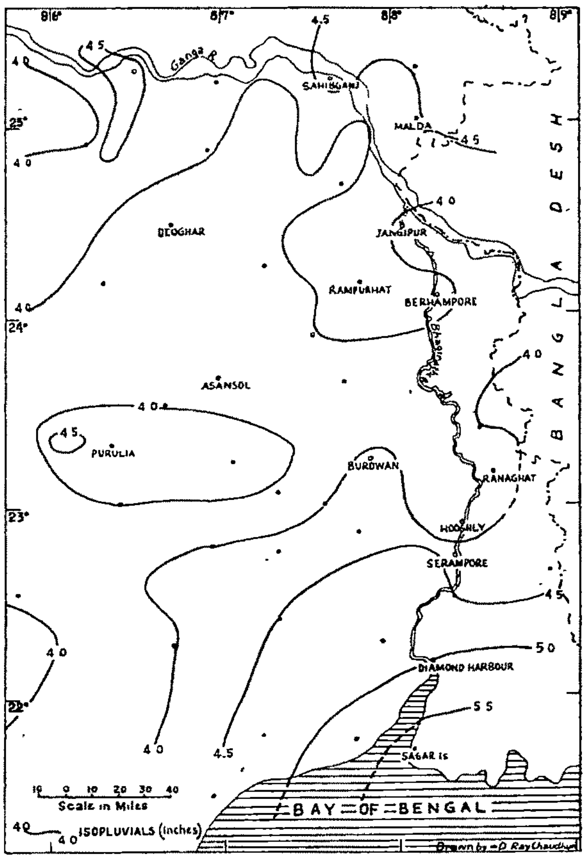


Fig. 3
Generalized chart of maximum 2-year 1-day rainfall over Bhagirathi-Hooghly Basin.

It has been observed from an examination of self-recording raingauge network in this area that the longest records of hourly rainfall are available in respect of Calcutta. This station has therefore been taken as a representative station within this basin for the short duration analysis of rainfall data. In this study 18-year (1948-1965) autographic rainfall

rainfall for these return periods. In recent years the US Weather Bureau (1963, 1964, 1965) has adopted this approach for the preparation of generalised charts of maximum rainfall for different return periods.

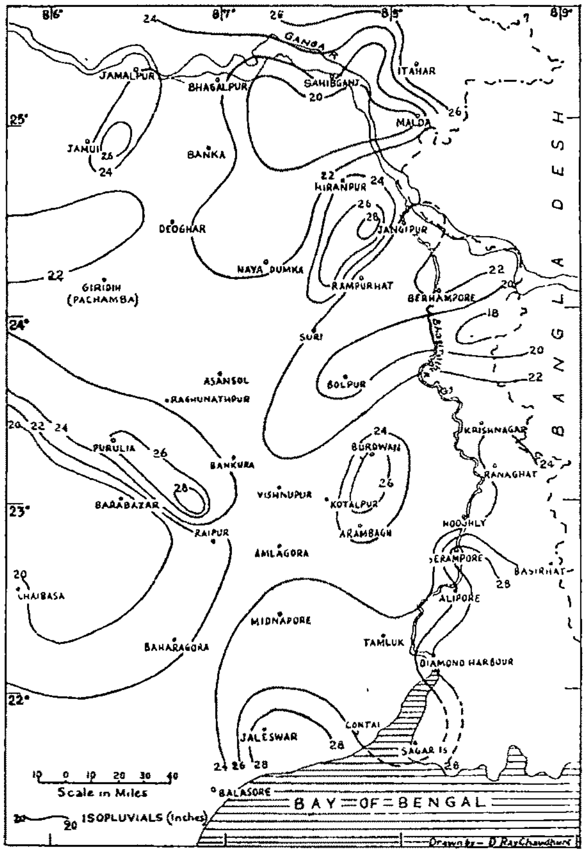


Fig. 2

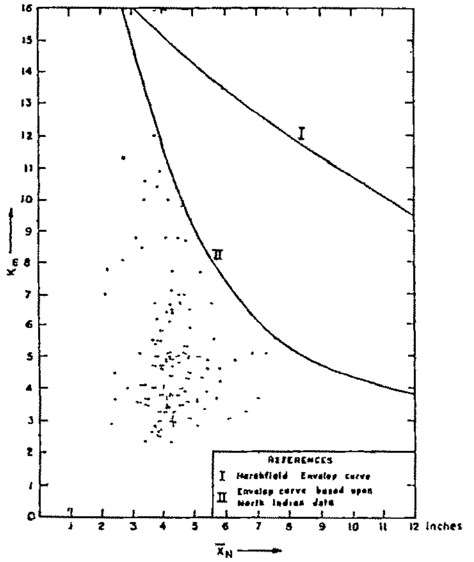
Generalized PMP chart for one-day duration over Bhagirathi-Hooghly basin.

The rainfall magnitudes obtain with the help of the nomogram (Fig. 5) have compared with those directly obtained by the Gumbel-Chow method. It has been seen that for most of these stations the values tally within ± 3%.

The rain estimates obtained above for different return periods refer to annual series data. To obtain the true amounts, the annual series values have to be converted into partial duration values upto 10-year return period. Beyond this, both the series are supposed to give identical values. The following are the conversion factors for the conversion of annual series into partial duration series as obtained by Dhar and Kulkarni (1970) on the basis of Utter Pradesh rainfall data :—

Return Period	*Conversion factor*
2-year	1.13
5-year	1 04
10-year	1.02

this region. By way of comparison Hershfield's enveloping K_m curve has also been drawn in Fig. 1 and it has been seen that by using K_m values from the Hershfield curve, extremely high values of PMP are obtained for individual stations in the problem area. Using K_m values picked up from Fig. 1 for 93 stations in the Bhagirathi-Hooghly region, PMP values were worked out by equation (III) and a smooth generalised chart of one-day PMP was prepared which is shown at Fig. 2. This chart can be used for obtaining PMP estimates for any point in this region for the planning and design of hydraulic structures whose failure cannot be risked.



Km as a function of mean annual maximum one-day rainfall.

Fig. 1

MAXIMUM ONE-DAY RAINFALL OF DIFFERENT RETURN PERIODS

In the case of small hydraulic structures such as culverts, bridges, etc. where cent percent safety is not required, the design estimates are based upon maximum rainfall of a certain return period. An attempt has therefore been made here to study the maximum one-day point rainfall over the Bhagirathi-Hooghly basin for different return periods from 2 to 100 years. In this study Gumbel's technique as adopted by Chow (1953, 1964) has been used in the analysis of daily rainfall data of 93 stations in and around the basin.

Dhar and Kulkarni (1970) have used this procedure in their study of maximum rainfall over Uttar Pradesh region. Using the same technique, maximum rainfall for one-day duration has been worked out for different return periods of 2, 5, 10, 25, 50 and 100 years for each of the 93 stations. On the basis of this data smooth generalised charts of 2 and 100-year rainfall have been prepared for this area which are shown at Figs. 3 and 4. A nomogram (Fig. 5) has also been prepared for obtaining directly the magnitudes of one day rainfall for the intermediate return periods for 5, 10, 25 and 50 years using the 2 and 100-year rainfall values from the generalised charts at Figs. 3 and 4. The nomogram (Fig. 5) can be used in the following manner for obtaining rainfall magnitudes for a station for the intermediate return periods of 5, 10, 25 and 50 years :

Pick up 2 and 100-year rainfall values for a station from the generalised charts of Fig. 3 and 4. Plot these values on the corresponding 2 and 100-year vertical intercepts of the nomogram. The two points are then joined by a straight line and the points of intersection of the straight line with 5, 10, 25 and 50-year vertical intercepts give the magnitudes of

$$K_T = -\left(1.100 + 1.795 \log_{10} \log_{10} \frac{T}{T-1}\right) \quad \ldots \text{(II)}$$

Hershfield used Chow's equation (I) in the form

$$X_m = \bar{X} + \sigma . K_m \quad \ldots \text{(III)}$$

Where X_m is the estimated extreme rainfall for a station for a particular duration, $\bar{X}$ is the mean of the annual series for that particular duration and σ is the standard deviation of this series.

The value of K_m in the equation (III) is determined in the following empirical way :

(a) Mean ($\bar{X}$) and standard deviation (σ) of extreme annual series for each station are worked out first by omitting the highest value from the series.

(b) The value of K_m is worked out by using equation (III) in the form

$$K_m = (X_m - \bar{X}) / \sigma \quad \ldots \text{(IV)}$$

In the equation (IV), X_m is substituted by the highest value of the annual series and the values of $\bar{X}$ and σ obtained at (a) above are substituted for these terms in the equation (IV).

Using the above procedure, Hershfield (1961) calculated the value of K_m for about 2650 stations which also included about 10% of stations from the heaviest rainfall regions of the world. The highest value of K_m obtained by him was found to be 15 (exact value 14.5) for one-day duration.

Using the above technique, Dhar and Kamte (1969) prepared a generalised PMP chart for the Uttar Pradesh region. In this study, instead of using the world envelope value of K_m, the regional envelope value of K_m was used as some workers (Wilson, 1963, Mazumdar and Rangarajan, 1966) have questioned the universal transposibility of any one value of K_m. The highest value of K_m for a duration of one-day for the Uttar Pradesh region was found to be 12.

Hershfild's Latest Technique For PMP

Hershfield (1965) revised his earlier approach in the light of further studies on this subject. These studies revealed that K_m is a function of storm duration and mean ($\bar{X}$) of the annual series. He also observed that K_m has a tendency to decrease with the increase of $\bar{X}$ for different durations. Plotting K_m against $\bar{X}$ for different durations of rainfall, he obtained a family of envelope curves. These curves give the highest value of K_m for a particular value of $\bar{X}$ for a given duration for a station.

Generalized PMP chart for the Bhagirathi-Hooghly basin

Instead of using Hershfield's enveloping K_m curve (which is based upon world record rainfall data) a similar enveloping curve was prepared (Fig. 1) based upon the K_m and $\bar{X}$ data of 502 stations in north India, whose rainfall data are available for 60 to 70 years from 1891. The authors feel that using the enveloping K_m curve based on Indian data will give a better estimate of extreme rainfall in records of Dum Dum observatory at Calcutta have been analysed for the months of May to October as more than 90% of the annual rainfall at this station is received during these six months.

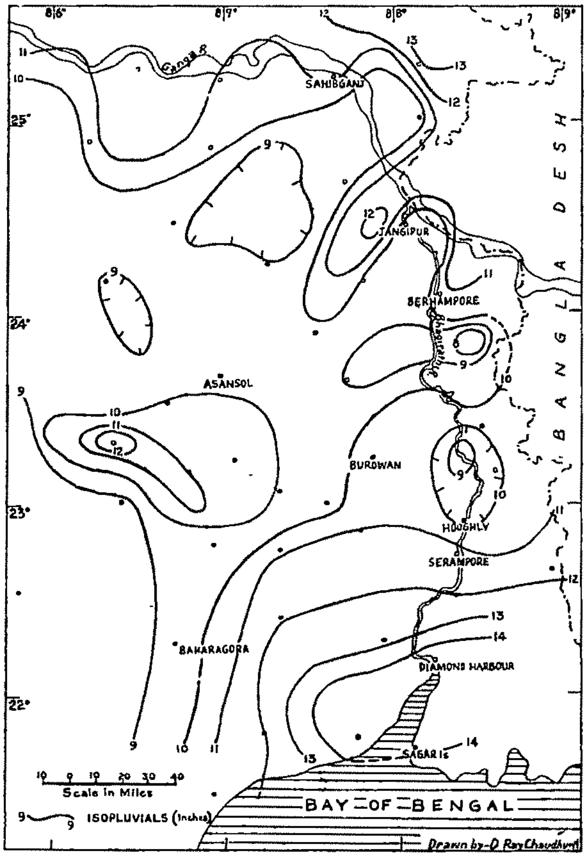


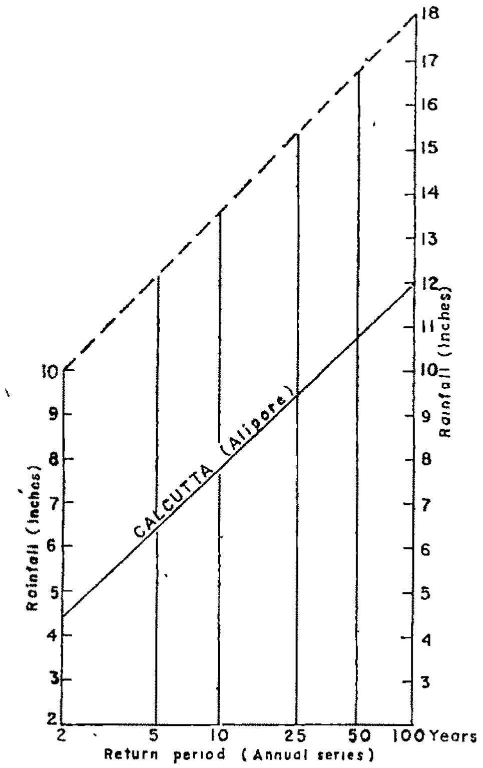
Fig. 4
Generalized chart of maximum 100 year 1-day rainfall over Bhagirathi-Hooghly Basin.

Frequency analysis of hourly rainfall for Calcutta

In this study clock-hour has been taken as the unit of study. The observed maximum rain amounts recorded during each of the durations of 1, 2, 3, 6, 12, 18 and 24 hours were picked up for each year of the 18-year period from a scrutiny of the hourly data. Using Gumbel-Chow (1953) technique the maximum rain intensities likely to occur in different return periods of 2, 5, 7, 10, 15, 20 and 25 years was worked out. Table 2 gives these rain amounts for various durations and return periods.

Analysis of heavy rainspell data for Calcutta

Heavy rain spells which have yield



Return period interpolation diagram for Bhagirathi-Hooghly basin.

Fig. 5

more than 3 inches in 24 hours or more were selected for this study. It has been observed that during the period 1948-65, there were only 25 such heavy rain spells at Calcutta. Maximum rainfall recorded in different durations of 1, 2, 3...24 hours in each of these 25 spells were then picked up. Average percentage ratios of maximum rain-fall recorded in each of the durations to that recorded in 24 hours were worked out and the same are given in Table 3.

From Table 3 it is seen that on an average 50 to 60% of 24-hour maximum rainfall is received in 6 hours and 75 to 80% is received in 12 hours. There have been cases when practically 95% of the 24-hour rainfall has occurred in 6-hour duration.

Time distribution of rainspells

Daily rainfall, as usually reported, does not represent the true 24-hour rainfall unless the entire rainspell has occurred within two observations, i.e. from 0830 IST of previous day to 0830 IST of date. This aspect of rainfall distribution has also been studied with the help of hourly rainfall data of Calcutta and the following average time distribution has been worked out:

(a) Observational 2-day rainfall occurs

TABLE 2

Maximum rain amounts (inches) for different durations and return periods.

	Return period in years.							
Duration (Hrs).	2	3	5	7	10	15	20	25
1	1.84	2.05	2.27	2.40	2.55	2.73	2.85	2.93
2	2.40	2.75	3.15	3.40	3.70	4.00	4.20	4.39
3	2.70	3.10	3.53	3.80	4.05	4.38	4.56	4.72
6	3.20	3.61	4.01	4.40	4.70	5.02	5.30	5.50
12	3.70	4.30	4.98	5.40	5.80	6.30	6.65	6.90
18	4.05	4.80	5.60	6.10	6.65	7.20	7.60	7.95

TABLE 3

Percentage ratios of 1, 2, 3 . . . . hour to 24-hour maximum rainfall.

Duration (Hrs)	1.	2.	3.	6.	2.	18.
Mean percentage	27	39	46	58	75	87
Median percentage	24	34	40	54	81	90
Highest percentage	56	76	84	96	99	100

in a duration of about 32 clock-hours.

(b) Observational 3-day rainfall occurs in a duration of about 48 clock-hours.

(c) Observational 4-day rainfall occurs in a duration of about 68 clock-hours.

An attempt has also been made to study the relationship between (a) Observational one-day and 24-hour maximum rainfall (b) observational 2-day and 48-hour maximum rainfall and (c) observational 3-day and 72-hour maximum rainfall. The following are the average relationships obtained from this study :

(a) Maximum 24-hour rainfall is about 11% more than the observational one-day rainfall.

(b) Maximum 48 and 72 hour rainfall are about 2% more than the observational 2-day and 3-day rainfall respectively.

These factors compare favourably with those obtained in USA where the average factors are 1.13, 1.02 and 1.01 respectively for the observational 1, 2 and 3-day rainfall respectively (US weather Bureau, 1961, 1964).

SUMMARY

The results obtained in the preceding sections may briefly be summarized as follows :

(a) PMP generalised chart for one-day duration for the Bhagirathi-Hooghly region has been prepared using the statistical technique developed by Hershfield. The PMP generalised chart is shown at Fig. 2.

(b) Maximum rainfall for return periods of 2, 5, 10, 25, 50 and 100 years has been calculated for about 93 stations in this region whose long period data are available for 60 to 70 years from 1891. Generalised charts of 2 and 100-year maximum rainfall have been prepared and are given at Figs. 3 and 4. A nomogram for obtaining maximum one-day rainfall for intermediate return periods of 5, 10, 25 and 50 years with the help of 2 and 100-year generalised charts has also been prepared and is given at Fig. 5.

(c) Short duration analysis of maximum rainfall, for one representative rainfall recording station in this region (viz. Calcutta) has also been carried out and the following results have been obtained from this study :

(i) Six hour maximum rainfall is nearly 50 to 60% of the 24-hr. maximum rainfall,

(ii) On an average observational 2-day rainfall occurs in a duration of about 32 clock-hours and similarly observational 3-day and 4-day rainfall occurs in 48 and 68 clock-hours respectively.

(d) To obtain 24, 48 and 72-hour maximum rainfall from an observational 1, 2 and 3-day rainfall, we may use the following conversion factors :-

(i) 1.11 for one-day maximum rainfall

(ii) 1 02 for 2 and 3-day maximum rainfall.

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REFERENCES

Bruce, J. P. and Clark, R. H. (1966) : *Introduction to Hydrometeorology* Pergman Press, New York.

Chow. V. T. (1951) : Tran. Am. Geo. Union, Vol. 32, No. 2.

Chow, V. T. (1953) : University of Illinois, Engineering Bull. No. 414.

Chow, V. T. (1964) : *Handbook of Applied Hydrology*, McGrow Hill Book Company, New York.

Dhar, O. N. and Kamte, P. P. (1969) : Ind. Journal of Met. and Geophys. Vol. 20, No. 1.

Dhar, O. N. and Kulkarni, A. K. (1970) : Indian Journal of Met. and Geophys. Vol. 21, No. 2.

Hershfield, D. M. (1961) : Journal of Hy. Div. Proceedings Am. Soc. Civil Engs. Vol. 87, No. Hy. 5.

Hershfield, D. M. (1965) : Journal American Water Works Association, Vol 57, No. 8.

Hershfield, D. M. and Wilson W. T. (1957) : Proc. Int. Assoc. Sci. Hydrology, General Assembly of Toronto, Vol. I.

Mazumdar, K. C. and Rangarajan, R. (1966) : Ind. Jour. Met. and Geophys., Vol. 17, April, 66.

Myers, V. A. (1967) : Tech. Memorandum WBTH Hydro. 5, U.S. Weather Bureau.

Wilson, W. T. (1963) : Trans. Am. Soc. Civil Engrs Discussion on paper No. 3431.

U. S. Weather Bureau (1961) : Tech. Paper No 40.

U. S. Weather Bureau (1963) : Tech. Paper No. 47.

U. S. Weather Bureau (1964) : Tech. Paper No. 49.

U. S. Weather Bureau (1965) : Tech. Paper No. 52.

World Meteorological Organisation, Geneva (1965) : Guide to Hydromet. Practices.

SOME CONSIDERATIONS ON THE DECAY OF THE BHAGIRATHI DRAINGE SYSTEM

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&
SATYESH C. CHAKRABORTY

Abstract

The economic importance of the Bhagirathi drainage system with reference to the port-industrial economy of West Bengal is well known. The obvious evidence of silting in the lower reaches of this river and the alarming disconnectedness of its headwater from the main channel of the Ganga or the Padma, have created sufficient anxieties over the last century, the contours of which are more or less well known.

The social and political contingency on many occasions directed many scientists, competent in this field, to devote their attentions to many specific issues to suggest several *ad hoc* measures to meet the above challenges. Their attempts are no doubt heroic, but these hardly provided data to permit scientific speculation about the cause of chocking up of the drainage channels on such a regional scale. The authors believe that there is an extreme lack of direction in the academic world regarding allocation of priority in the selections of the fields of investigation, the results of which may prove relevant to explain the causative sequence of the decay of the drainage system of the Bengal deltaic area.

This paper seeks to furnish a few tentative parametres in such a way as to provide an overview for those interested in more detailed research. The authors propose to approach the objective by first giving an outline of the existing knowledge upon the tectonic and physiographic set of the Bengal delta area, then by describing the topographical and hydrological features of the Bhagirathi Valley and finally, by working out a scheme which is necessary and probably sufficient to explain the observed phenomena in the earlier sections.

One of the striking phenomena of the deltaic Bengal of recent times is the state of decay of its river channels. The decay of the Nadia rivers in the 17th and the 18th centuries, the continual flight of the principal flow of the Ganga along its more easterly distributaries, the rapid silting in the lower section of the Bhagirathi-Hooghly channel, etc., are some of the more salient expressions of this decay. Viewed in the light of economic importance of the Bhagirathi drainage system to the port-industrial economy of West Bengal, the situation is indeed disturbing.

THE TRAP OF CONTINGENT-SPECULATION

Throughout the last hundred years or so, the increasing rate of siltation in the lower reaches of the Bhagirathi river deepened a sense of anxiety, for it threatened the very survival of the Port of Calcutta. It is true that political and social contingencies, arising as it did from the afore-mentioned anxiety, provided many opportunities to competent technicians to enquire into the specific contours of the threat and to suggest *ad hoc* measures to meet the challange. For instance, the port authorities of Calcutta, presumably accepting such *ad hoc* remedies, indulged in a programme of recurring dredging to keep the sea-bound channel of the Bhagirathi just sufficiently open to permit the continuity of the port-functions. Indeed such a programme is heroic, for they are doing it for more than one hundred and thirty years ! Unfortunately however, such heroism hardly provided sufficient information to permit scientific speculations about the cause of chocking up of the drainage channels on such a wide regional scale. What is perhaps more disturbing in this context is the fact that in the world of academics also there has been an extreme lack of direction in the matter of selection of priority for choosing relevant fields of investigation, the results of which might be collated to work out causal sequence of decay of drainage system in the Bengal deltaic region. Such absence of concensus in the academic world appears funny when we review it against the deep seated anxiety in the economic and political world of Bengal.

Economic or political expediencies however tend to perpetuate contingent speculations. We have many examples of it. For instance, it was believed, some forty years ago, that the extensive erosional functions of the Damodar thalweg could be the principal circumstance for siltation in the Bhagirathi. Such a speculation projected itself for the acceptance of a 'multi-purpose-scheme' for the Damodar drainage network, designed to control erosion and flood, to distribute water for irrigation and facilities for recreation, and to produce electricity and fish. Since then, the Damodar Valley Project has been significantly completed. But that has hardly reduced the necessity of dredging the lower Bhagirathi channel. This is a significant illustration of the 'trap' that contingent speculations produce. For, the earlier speculation having been once successful in winning investmental support increases in subsequent time the entrepreneurial risks of investment in other speculative fields. It skillfully pops up only to direct further investment for such speculations alone which are not likely to upset the deductive-base of the earlier speculation. For example, the 'logic' of the concept of the Damodar Valley Project is now-a-days lending itself to a split in the earlier contention : one challenging the veracity of flood-control cum irrigation type of proposition for rivers in the monsoonal tropics, and the other, like desperate cliff-hangers, are trying to rationalize the situation through a search for further opportunities of proliferation of the major components of 'multipurpose' physical planning. But none would recognize that between these two contending speculations at least one scientific fact has emerged. Now it is obvious that the erosional activity in the Damodar thalweg has not been a significant causal component of siltation in the lower course of the Bhagirathi channel. The fact is proven, for dredging is more necessary now than it was before the reservoirs were constructed on the Damodar network.

The current speculation, designed once again to meet the economic contingency of the port of Calcutta, hovers upon the concept of flushing the Bhagirathi by bringing in additional water from the adjacent drainage systems. It has been observed that the shoals of Lower-Bhagirathi are greatly reduced in size just after the monsoonal floods. Therefore, Farakka Project is looked upon as a specific measure to extend or prolong the period of flushing the lower course of the Bhagirathi channel.

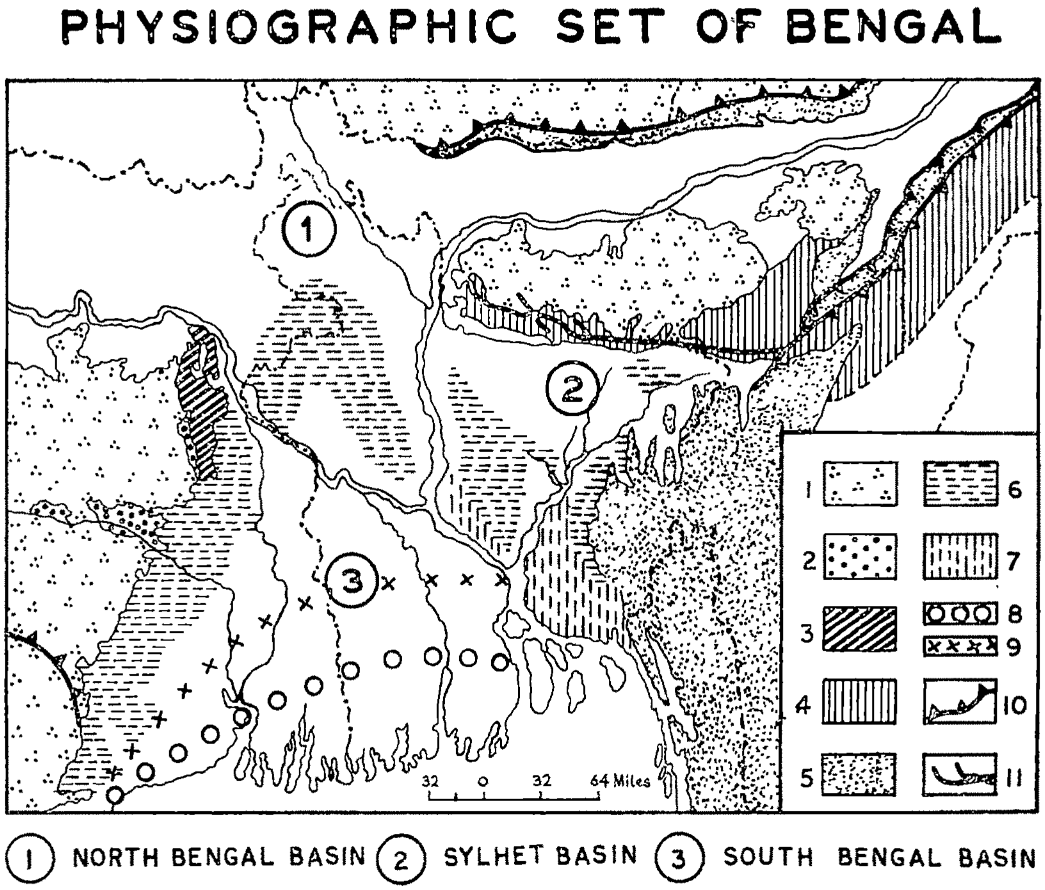
We are not suggesting that Farakka Project will or will not solve the basic malady of the port economy of Calcutta. We only want to emphasise that there is no objective reason to believe that a project like Farakka can at all reverse the process of decay of the Bhagirathi or at least counteract as to hold it suspended. At the same time, we believe that by putting together the existing knowledge regarding the tectonic and physiographic format of the Bengal delta area along with the analysis of the topographical and hydrological features of the Bhagirathi valley it is possible to provide an overview of the objective situation against which the veracity of the Farakka Project can be estimated. This overview is also expected to provide some clues for working out a rationale for further research in this field. We believe that such researches can help us to overcome the 'traps' of contingent speculations in the long run.

HOW DELTAIC IS THE BENGAL DELTA

It may sound enigmatic, but not all parts of the tract known as Bengal delta had formed by the commonly assumed process of reverine alluviation at or near the base level of erosion. Both physiographic and tectonic evidences indicate that a substantial part of it had formed by recession of sea concomitant with upliftment of the basement complex of the Bengal basin during the Pleistocene period (Sengupta, 1966 ; Chakraborty, 1970). It is now well known that Bengal basin is tectonically linked with Naga-Lusai orogeny and that the Archaean shield of Chotanagpur has warped downwards in an easterly fashion admitting thereby both deltaic and littoral deposition upon it. The boundary line between the miogeosyncline and the eugeosyncline passes below the Bhagirathi valley and both these units are still quite mobile. This tectonic format of the Bengal basin has to be taken into account in order to understand the hydraulic features of the Bengal delta of today. A first approximation of such an understanding is attempted here by taking a stock of diversity of physiography in this part of the world.

The delta of Bengal is the largest of its kind in the world. It is commonly believed that the whole of undivided

Bengal is a part of this delta (Bagchi, 1944). But we feel that the area generally bounded by the Bhagirathi river in the west and the Padma in the east should be called the proper delta in the physiographic sense of the term. A complete rationale of this proposition has been worked out before (Chakraborty, 1970). However, it should be mentioned that adjacent to this major-delta there are a number of similar (i.e. deltaic) but smaller units formed by the numerous rivers falling into the Ganga-distributary-system. The origin of these sub-deltas or para-deltas are, no doubt, related to the aforementioned tectonic format of the Bengal basin. But, for its size alone, the major-delta requires a more complex set of analysis in order to get any insight into the circumstances of its origin. The rationale for adoption of different analytical framework for the different regional components



1. Archaean-Granitoids, 2. Gondwana Sedimentaries-Faulted Basin, 3. Rajmahal Trap (Plateau), 4. Eocene to Oligocene (Naga-Patkoi Hills), 5. Mio-Pliocene (Lushai Hills), 6. Lateritic-Ferallitic Landforms, 7. Tippera-Noakhali-Barind Plain, 8. Approx. limit of land built by Marine Agencies, 9. Approx. Southern Boundary of Riverine Delta, 10. Thrust Faults, 11. Normal Faults.

Fig. 1

of the Bengal basin is also well known (Chakraborty, 1970).

The most striking feature of the Bengal delta is the remarkable stability of the shoreline orientations and their azimuthal co-ordinates over the last two hundred years. Since the time of Rennel (1781) the shoreline of the delta base has not changed. Such a phenomenon can be accounted for by assuming that either (1) the Padma distributaries are not bringing enough sediments to the sea, or (2) whatever sediments that the Padma distributaries do bring in are getting washed away towards deeper parts of Bay of Bengal by off-shore drifts. Of these two propositions, the material evidences in the region indicate that the first one is more valid. We shall examine the second proposition and show that this is a null hypothesis.

The continental shelf subjacent to the estuaries of the Padma distributaries is a very shallow one and extends for miles into the sea There are also evidences to indicate the presence of off-shore drifts : one proceeding eastwards along the Coromondol and the Northern Sirkar coast of Peninsular India and the other along the Arakan-Chittagong coast line towards west. These two drifts converge somewhere near the estuary of the Matla river, one of the distributaries of the Padma, and their combined flow moves southwards. This is precisely the location of the 'swatch of no grounds'—a classic example of submarine cannyon formed through gravity flow of drift-materials. We wish our readers to note particularly the fact that this submarine canyon is not associated with any of the principal distributaries of the Bengal delta. We wish to mention that the headwaters of the Matla estuary are in complete state of decay. Hence, we admit that the drift-materials are derived from sources that are basically independent of the process of riverine deposition in the Bengal delta area. We also admit that the off-shore drifts are the principal determinants of the present orientation of the continental shelf in this part of the world and also of the remarkable stability of the shoreline-orientation of the base of the Bengal delta.

We may now examine the first proposition and see to what extent this is acceptable. At the outset we must state that data on water and silt discharge for any of the Padma distributaries at or near their estuaries are not available. Hence we need to depend on indirect evidences. In this context, the big shoal in the Bhagirathi near the town of Halisahar is interesting in more than one sense (Saha, 1966).

This shoal is flanked on either side by channels of water. A study of the texture and structure of the materials composing this shoal indicate quite a complex origin. The upper layers are distinctly riverine in origin, whereas the lower beds are decidedly marine-estuarine in composition. The line of unconformity between these two is located above the mean water-level in this tidal section of the river. The following considerations appear to emerge from the above data :

i) the sea-face of the Bengal delta was very much further inland in recent times than it is today ;

ii) there has been a significant negative change in the base level of erosion for the Padma distributaries in recent time

(N. B. The mobility of the basement complex of the Bengal basin permits such diastrophic adjustments) ; and

iii) the probability of alluvial aggradation in the terrain upstream of this shoal is minimal (N. B. The line of unconformity marking the facies change is now located above mean water level of the river.).

The above considerations lead us to believe that the marine and fluvial-land-aggradation processes are now juxtaposed somewhere in the terrain downstream of the shoal of Halisahar. The problem is to locate the tract more exactly. In the absence of data on the discharges of the rivers, this certainly cannot be delineated accurately. However, there are some indirect evidences to specify the general location of this zone.

These indirect evidences can be reviewed in the following order :

(i) The lower reaches of the Bhagirathi is distinctly tidal. The landward limit of this tidal section of the river extends more or less upto the city of Santipur. Downstream of this city, the base of the river-banks is distinctly higher than the adjacent land almost upto the confluence of the river with the sea. This phenomenon cannot be related to the processes of natural levee formation, for there are both physical and corroborative historical evidences to show that these high banks are products of reinforcement by human agencies designed for the purpose of land-reclamation for agricultural purposes. These reinforced banks are sources of continual hazards to the agrarian economy in this part of the world at times when the tidal-bores reach phenomenal proportions. These bores not only bring saline water but also considerable amounts of marine-estuarine sediments, silty to sandy in composition. Obviously these sediments are derived through tidal scouring of the floors of the shallow continental shelf lying at the base of the delta.

(ii) The shoals located to the downstream section of the Bhagirathi below its confluence with the Damodar tend to reach their maximum sizes before the monsoons. The size of these shoals are very much reduced immediately after the monsoonal floods inspite of the fact that all the right-bank tributaries, like the Damodar, Rupnarayan, Kangsabati, and Haldia, bring enormous amounts of silts with their floods. This clearly demonstrates that the growth of the shoals following the seasons of flood has little to do with riverine sedimentation for the simple reason that silt-load of a river is proportional to its volume of discharge. As during summer months their discharges are reduced to mere trickles, the growth of the shoals in this very season should be explained only by accepting the mechanism of tidal scouring of the floor of the shallow continental shelf. In other words, we are to accept that marine agencies are still engaged in the work of land-building within the Bengal delta region.

(iii) There are chains of huge swamps and marshy tracts which extend from the southern part of the District of Midnapore, in a north-easterly fashion, through the districts of Howrah, 24-Parganas, Jessore, Khulna and Faridpur. These swamps or marshes are in most instances brackish in character. These are also connected to the sea through tidal creeks. There are historical evidences to indicate, the case of the Salt Lake of Calcutta being most well known, that these marshes or swamps are being filled up by both riverine and tidal sediments. Their earlier sizes are consequently getting reduced in appreciable speed. Therefore the conclusion, that these swamps and marshes are the hollows and depressions left by the receding sea concomitant upon diastrophic upliftment of the basement complex of the Bengal basin, become inevitable.

In sum, the general location of these swamps may be accepted as the broad zone where the marine and riverine land-building agencies are now juxtaposed. To the south of this zone, marine agencies dominate over the riverine activities. This will perhaps explain how the riverine silts, being used up to fill these hollows, have not been able to produce any noticeable advancement of the delta base since the time of Rennel. As a corollary, we may further claim that the decay of the lower section of the Bhagirathi is primarily a function of marine land-building activities in the seaward half of the Bengal delta.

MOBILE BASEMENT AND THE STRANGE PHENOMENON OF MORIBUND STREAMS

The mobility of the basement complex of the Bengal basin referred heretoabove, is likely to have a correspondingly complex expression on the resultant topography. We propose to review the broad features of the topography with a view to derive some idea about the nature of diastrophic adjustment that the basement complex underwent in sub-recent times. These topographical features can be reviewed in the following order :

(i) There are ample historical evidences to indicate that the main flow of the Padma used to pass through its more westerly distributaries in the past. Each of the distributaries of the Padma, like Jalangi, Ichhamati, Bhairab, Churni or Madhumati, at one time or the other, used to carry the principal discharge. It is believed that this shift of the principal discharge has been from west to east. Consequently we are to assume that the surface gradient of the Bengal delta obtained an easterly attribute consequent upon the movement of the basement complex.

(ii) All the right bank tributaries of the Bhagirathi below Nabadwip-Santipur have described rightangular bends towards south. This is observable with the rivers like the Damodar, Rupnarayan, Kangsabati, and the Haldi. Downstream of their respective rightangular bends, all these rivers, along with the Bhagirathi below Nabadwip, have failed to form natural levees. The bases of their banks are no doubt higher than the subjacent flood-plains ; but these are results of human intervention as we have already mentioned. It seems that the courses of all these streams have been prograded towards the sea. Hence we are to assume that the surface gradient of the Bengal delta obtained also a southerly attribute consequent upon the movement of the basement complex.

(iii) These two sets of evidences can be admitted only under the assumption that the movement of the basement complex of the Bengal basin led to recession of the sea-face towards south-east, exposing thereby an inordinately large area upon which the courses of the older streams would be prograded. Concomitant upon such progradation, siltation will proceed from the river channels upon this newly exposed land surface, leaving the interfluves relatively unfilled and full of swamps of brackish water. We have already located such swamps, stretching as a chain, from south-western part of the Bengal delta towards north-east as depicting a broad zone where the marine and riverine land-building agencies are presently juxtaposed.

(iv) Assume that the shoreline before the post-Pleistocene recession extended from Dantan P. S. in Midnapore district through Khanakul P. S. in Hooghly district to a point near the confluence of the Padma and the Jamuna in Bangla Desh. The relatively juvenile drainage to the north of this alignment offers a striking contrast to the interlacing drainage pattern interspersed with brakish swamps lying to the south of this line. Even the soils on either side of this line are different in the sense that these are more akin to the post-Miocene older alluvium in the north, while in the south these are degraded varieties of halogenic groups, commonly found in coastal littoral tracts. The line joining the elbow-bends of the right-bank tributaries of the Bhagirathi, like the Damodar, Rupnarayan, Kangsabati, etc., it is interesting to note, is strikingly parallel to the alignment of this hypothetical shoreline. We should further note that the alignment of the hinge between the buried shield and the geosyncline within the basement complex of the Bengal basin is also parallel to the alignment of this hypothetical shoreline. In the same manner the alignment marking the zone of facies change between the sediments of the shallower and deeper parts of the geosyncline is parallel to this hypothetical shore line. Such regional consistency of the tectonic frame, ecological variations of geosynclinal sedimentation, and topographic variations merely indicate that the post-Pleistocene recession of the sea-face is a surface expression of the deep seated movement of the basement complex of the Bengal basin. We must especially note that the angular displacement of such a receding sea-face will ensure greater progradation of the more easterly distributaries of the Padma.

(v) A corollary to progradation of streams consequent upon upliftment of the basement complex would be rejuvenation of the streams in the older deltaic area which are likely to contribute to the development and growth of juvenile tributary net-work at least in the inter-fluvial tracts. But the strangest fact of this terrain is that all the older distributaries of the Padma, instead of showing pronounced signs of rejuvenation, are in moribund state. Such contrapuntal disposition of decayed streams set against opportunities of rejuvenation appears to be the most singular phenomenon of the physiography of this part of the world. The problem is to explain it.

Before we indulge in a search for an 'explanation', we should admit that the moot point, that will explain these contrapuntal phenomena of decayed streams set against tectonic opportunities for rejuvenation, in reality concerns a search for reasons as to why the rivers failed to rejuvenate themselves. The other part of the story, i.e., the decayed state of the streams, would then become an obverse expression of it. Obviously enough, for such a 'search' we need to investigate the situation at the off-take points of these distributaries from the Padma. From 1964 the authors have been investigating the conditions prevailing at the off-take points of the Bhagirathi and the results of this study appears to provide reasonable opportunities to reconcile the above mentioned contrapuntal phenomena of tectonic and physiographic situations.

MECHANICS AT THE OFF-TAKE POINT OF THE BHAGIRATHI

Within historical times, the Bhagirathi has experienced a number of changes of its off-take positions in relation to the parent river, i.e., the Ganga or the Padma. The more well known of these off-take points are situated at Dhulian, Suti, and Giria, each one of which had assumed importance within the last two hundred years. The characteristic circumstance of such changes has been associated with the opening of a new off-take point as the former one got closed. Throughout these periods, there has been a consistent shift of the off-take points towards east and corresponding diminution of supply of water from the parent river. Whether such a situation arose out of alluviation at the heads of these off-take points, of tectonic change (Morgan & McIntire 1959), of shifts in the balance of the delta due to change in river-courses in some place or the other (e.g. the great shift of the Tista), or of secular swing of the river to the east, are questions which admit of large and inconclusive debate. None of these hypotheses can, jointly or severally, account for the three unique phenomena of the Bhagirathi near its off-take points from the Padma. These are :

1. Consistent eastward shift of the off-take points ;
2. the obtuse-angular bend of the Bhagirathi at the section of its initiation as a distributary with reference to the south-east flowing river Padma ;
3. the reverse gradient of the Bhagirathi towards the Padma in the initial section of this distributary.

In the remote past and probably before 2000 B C., the off-take at Dhulian was active (Bhattasali, 1941). The site as identified ordinarily, was near the Dhulian Ganga railway station. In August 1964 the authors visited the place and identified the site of the now deserted Dhulian Ganga railway station. But the off-take point, together with the channel of the Bhagirathi, was found to have been completely engulfed by the Ganga. Local enquiries revealed that such a disastrous bank erosion by the Ganga took place some 25 years ago following a high flood. Today the Ganga at Dhulian off-take point is about three and a half mile wide containing a shoal of about a mile in width. But there was no trace of the old Bhagirathi river anywhere.

It is known that after the closure of Dhulian, the off-take point shifted to Suti. Like any normal distributary, the angle formed by the Bhagirathi and the

Ganga was decidedly less than a right-angle. But subsequently, it is said, the angle gradually changed into an obtuse one before the off-take point got finally closed. The remnant of the old channel can still be seen between the *mouzas* of Suti and Chak Purnapara. This channel is about two miles long and a couple of hundred feet wide, full of rain-water pools, often inundated by flash flows of the Ganga in high spate. Even then the depth of water within this channel hardly exceeds three to four feet.

As the Suti off-take point got closed, a new exit formed at Giria. Once again the angular distance between the parent river and the distributary was decidedly acute. However it gradually changed to obtuse angle, in which disposition it is still found today. And of course the off-take point is closed for all practical purposes. The closure of the Giria off-take was taken note of for the first time on November 26, 1919. And what a cataclysm it was! On November 28, 1919, one day before the closing of the entrance, the Bhagirathi near Giria recorded a discharge of 12,870 cusecs. And on December 1, 1919, four days after the closure of the entrance, the Bhagirathi received a discharge of 446 cusecs only, which amount could be entirely explained by percolation-factor alone (Hyden & Pascoe, 1919).

When the Ganga experiences flood, the Bhagirathi also gets a share of it through the Giria off-take point. For example, the discharge increases from a mere fifty cusecs or less to 100,000 cusecs or more at Jangipur, which is roughly seven miles downstream of Giria on the Bhagirathi. But such a fortune is indeed ephemeral, for it lasts only for two months or so, from the beginning of July to the end of August. For the rest of the year, the approach of the river at Giria is a dry bed with a few pools of shallow water here and there. The bed or floor of the Bhagirathi near the off-take point at Giria looks like a window or hanging valley about fifty feet above the corresponding floor of the Ganga. It is also possible to discern a surface flow of water from the Bhagirathi to the Ganga at Giria. Water appears to percolate through the unconsolidated sands from such a place as Jangipur, which is 7 miles down stream to reach the Ganga level at Giria. The surrogate of topographic features suggests as if the Bhagirathi is getting truncated from the parent stream.

HYDRAULICS OF TRANSFORMATION OF OFF-TAKE POINT

Since 1964, the authors have been closely observing the sequence of topographic orientation at the Giria off-take point with a view to identify the principal forces that are responsible for the changes. It is seen that the hydraulics of transformation of the Giria off-take point can be explained entirely by Newton's Experimental Law on Collision of Bodies in Fluid Media (Das & Mukherjee, 1966). This law can explain how an acute angular orientation of the distributary at the off-take point gets transformed into an obtuse angular one as long as the conditions of collision are available. That the rotational force of the earth has little to contribute to the hydraulics of such transformation at Giria is also clear. It is necessary to find out the connectivity between the basic premise of the above law on collision of bodies and the physical conditions prevailing at Giria off-take point.

As a first approximation of this law, we may state that the two paths of a moving body before and after collision with a fixed body describe equal angles with the common normal at the point of collision. Particles will tend to drop in moving fluid media when the velocity before collision becomes less than velocity after collision. As we have already stated that the closure of the Dhulian, Suti, and Giria off-take points are functions of deposition by the Ganga at these entrances, we must believe that the ratio between the velocities of the colliding body before and after collision did change in such a manner that the later exceeded the former over time. Such a change of ratio in a moving fluid can occur through reduction of velocity of the incident flow (which is the approximate velocity of the moving particle before collision). In an active river such reduction of the velocity of the incident flow can take place only when the path of the colliding body after collision cuts across the vector of the flow of the river. As the path of the reflected particle is a function of the common normal at the point of collision, we must admit that the temporal orientation of the surface of collision is the primary determinant of subsequent reduction of the velocity of incident flow in the parent river and of ultimate closure of the off-take point through deposition of sediments. The point therefore is to see whether the surface of collision is actually changing at Giria.

DIAGRAMMATIC SKETCHES SHOWING THE MECHANISM OF OBTUSE ANGULAR OFF-TAKE FORMATION OF THE RIVER BHAGIRATHI AT GIRIA

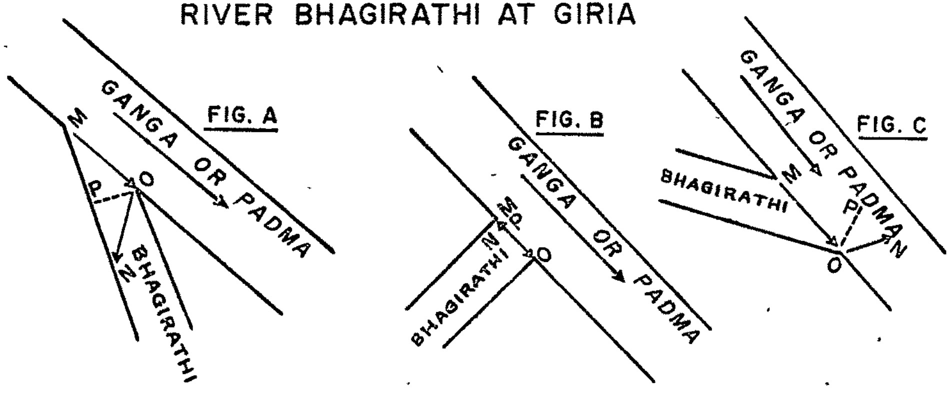


Fig.—A

The flow MO after meeting the bank at O traces the path ON when OP stands for common-normal.

Fig.—B

The flow MO after meeting the bank at O deflects backwards as ON, when OP stands for common-normal.

Fig.—C

The flow MO after meeting the bank at O traces the path ON when OP stands for common-normal.

Fig. 2

Since 1964 it was noticed that the dry season opening of the off-take at Giria was getting reduced. In January 1970, it was only 10 feet wide. Commensurate with constriction of the entrance passage, there was a corresponding prolongation of the right bank of the off-take point into the parent river consequent upon sedimentation. In the same order the left bank of the off-take point was receding by the colliding currents of the parent river. The orientations of these two banks are radically different from one another. While the right bank with the regular and growing promontory is convex, the left bank with a cliff like receding scarp is concave in reference to the parent river. The concavity of the left bank was such that it reflected the colliding bodies right against the vector of incident flow of the parent river. The consequent acceleration of the rate of sedimentation is therefore an easy guess.

The cliff on the left bank of the off-take point is composed of easily erodable sandy loam and has a relative elevation of about 30 feet. Underneath this unconsolidated sandy loam, there exists a bed of hard blackish clay intermingled with calcareous concretions, which is difficult to cut but easy to slide over. Even during the summer months the shallow currents slip over this clay bed and cause toe-erosion at the base of the loamy overburden and make the left bank recede consistently. Such is the manner by which the initial acute-angular orientation of the channel at the off-take point ultimately got transformed into an obtuse-angular one. The ultimate closure of the entrance through sedimentation is of course a function of the hydraulics of such transformation. (Fig. 2)

FROM A PARTICULAR EXPLANATION TO A GENERAL HYPOTHESIS

From the above analysis of the hydraulics of transformation of the Giria off-take point, we need not suspect that this will be true for all river systems in all parts of the world irrespective of their physiographic history. On the contrary, a similar hydraulics will operate only when the off-take point of a distributary shall act as a reflector or surface of collision to the incident flow of the parent stream. At Suti and Giria, we have found that the bed or floor of the distributary is lying above the corresponding floor of the parent river in the form of a window, wind-gap, or hanging valley. This relative disposition of the off-take point with reference to the parent river permitted it to function as a surface of collision to the incident flow of the parent river. The problem is to account for the origin of such a disposition of the bed of the distributary with reference to the parent river.

It is necessary to recognize that the parent river at Dhulian, Suti, or Giria has been more competent to exhume its own bed than the Bhagirathi distributary. It is also necessary to note that the Bhagirathi is the most westerly of the Padma distributaries. Hence we should enquire whether the Padma has been similarly competent in relation to the more easterly distributaries also.

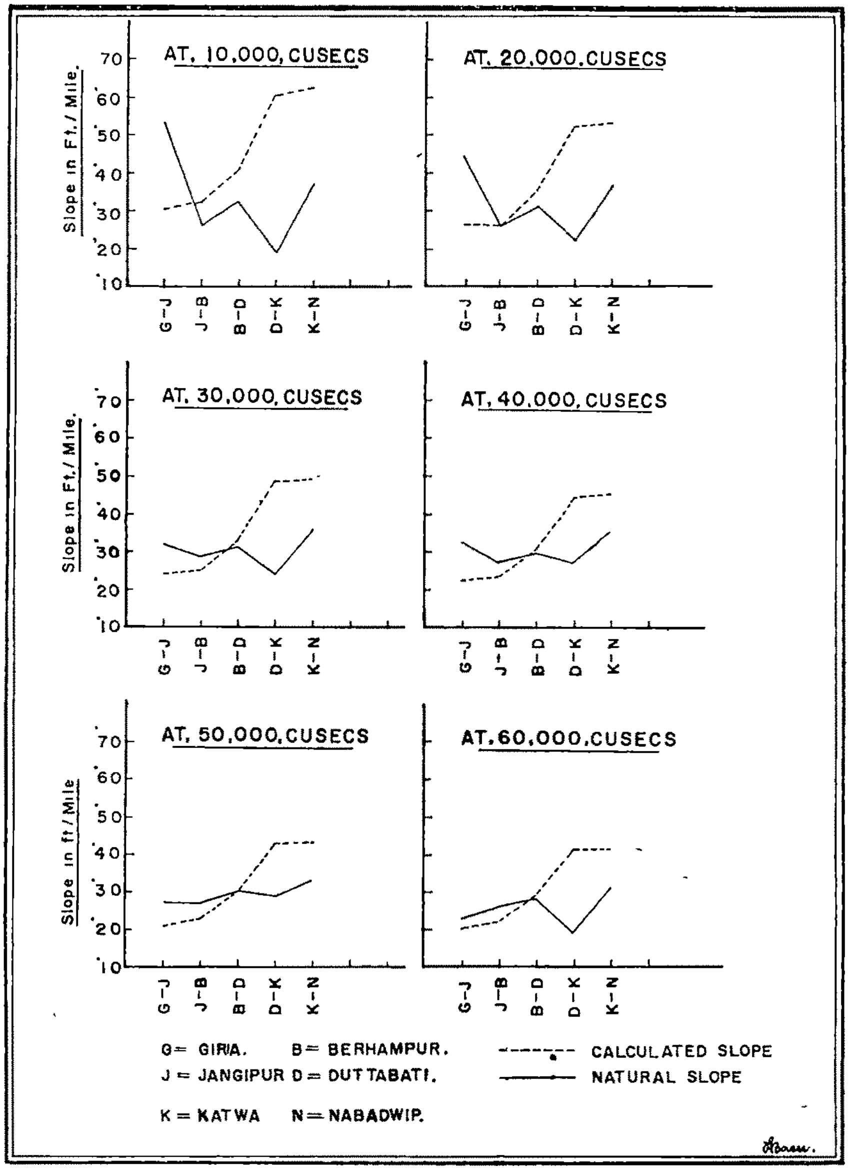
The authors in this context did not get opportunity to physically verify the situations. Nevertheless, from any detailed map of the region, it is easy to notice that the orientations of all the distributary channels, viz., Mathabhanga, Bhairab, Jalangi, Churni, etc., with reference to the Padma bear an obtuse-angular relation-ship. In all instances, the beds of the off-take channels are in elevated states with reference to that of the Padma. Consequently we are permitted to conclude that the current moribund state of the Padma distributaries is not a function of aggradational chocking of their respective channels as is common in deltaic situations. On the other hand, one should explain it in terms of the greater competence of the parent river to exhume its own bed than that of the distributaries. This phenomenon is so ubiquitous over the region that we are required to explain it in terms of a process that will hold good for the entire region.

We have already stated that due to deep seated movement of the basement complex of the Bengal basin the sea-face has receded towards south-east in this part of the world. While this displacement has been minimal in the western part of the Bengal delta, it has been widest in the east. Consequently, the knick points so produced will be furthest from their respective off-take points the more westerly the distributary is. In other words, the knick point on a western distributary will take a longer time to reach its off take point than that on a eastern one. Within this regional set, a similar knick point will also develop on the parent river. As the rate of headward migration of the knick points is proportional to the volume of discharge through the channels concerned, it is likely that the Padma, enjoying the largest discharge, shall admit the fastest migration of its own knick point. The Padma knick point must have had overtaken the other knick points long before these could arrive at their respective off-take points. Such differential migration of the knick points should not only lead towards beheading of the off-take points but to the formation of obtuse-angular off-take channels also. This must be the key to the strange situation where we find moribund channels in a region enjoying a negative change in the base level of erosion.

The work of adjustment to such a situation has indeed been more difficult for the Bhagirathi than any other distributary of the Padma, for this western most distributary has a tributary network of its own. These tributary streams, being rejuvenated by similar concurrent changes in their base levels of erosion, have been pouring in great amounts of sediments into the Bhagirathi, which certainly impeded the headward migration of the Bhagirathi knick point. The matter was so delayed that at Giria, except for the rainy season, the water of the Bhagirathi now empties into the Ganga. Even from Jangipur, 7 miles downstream, water now percolates through the unconsolidated sands to reach the Ganga level at Giria. These we have already mentioned. This upper most section of the Bhagirathi, from hydrological considerations, is describing practically a reverse gradient with reference to the rest of the channel. It has all the more reduced its capacity to transport its own bed load. And this failure to carry its own bed load is the principal attribute of the moribund state of the Bhagirathi river as it is for any other distributary of the Padma in this part of the world.

JUST HOW MORIBUND THE RIVER IS

In order to find out the minimum condition necessary for the Bhagirathi to carry its own bed load a short exercise in accounting was undertaken. The principles involved in this accounting are very simple indeed. We know that the slope necessary for movement of bed load is



Superimposed curves of the Hydraulic slopes of the River Bhagirathi, at varying Discharges

Fig. 3

directly proportional to the size of particles to be moved and inversely proportional to the volume of discharge. Dr. N K. Bose, former Director of the River Research Institute of West Bengal, introduced the following equation (Bose, 1948):

$$S.10^3 = 2.09 \frac{m^{.86}}{q^{.21}},$$

where $S\ x\ 10^3$ = the slope in feet per 1000 feet, m=mean diameter of the particle in mm., and q=discharge in cusecs. This equation has been used to calculate the slope necessary at different sections of the Bhagirathi at different hypothetical discharges varying from 10,000 to 60,000 cusecs. (Fig. 3). The Bhagirathi was divided into five sections or reaches and from several silt samples collected from each reach the mean diameter size of the particles were determined as follows:

Reach No. 1 : Giria to Jangipur : 0.144 mm
Reach No. 2 : Jangipur to Berhampur : 0.155 mm
Reach No. 3 : Berhampur to Duttabati : 0 209 mm
Reach No. 4 : Duttabati to Katwa : 0.322 mm
Reach No. 5 : Katwa to Nabadwip : 0 328 mm.

These calculated values of slopes were then compared with the natural hydraulic slopes or observed values of the slopes at different reaches. Following considerations appear to emerge from the above comparisons:

(1) There has been a consistent increment of the mean diameter size of particles as we proceed downstream along the Bhagirathi. The most phenomenal increment has taken place between Reaches 3 and 4, caused by sedimentation from the Dwarka and the Ajay tributaries.

(2) With the hypothetical discharge below 10,000 cusecs, the observed slopes are less than the calculated slopes in all the reaches. This implies that under such situation (e.g., during summer season) there is an almost complete suspension of bed load transportation in all the reaches.

(3) With the hypothetical discharge above 10,000 cusecs but below 20,000 cusecs, the observed slope is greater than the calculated slope only in reach No. 1. This implies that this one is the only section of the stream which becomes efficient with the least increment of discharge (viz., during monsoon when water from the parent river enters the off-take channel).

(4) Reach Nos. 2 and 3 become efficient only when the discharge is raised above 20,000 cusecs.

(5) Reach Nos. 4 and 5, in turn, become efficient only when the discharge is raised above 60,000 cusecs.

The above exercise is indeed interesting, for it demonstrates that the Bhagirathi is incapable of transporting its bed load efficiently under existing hydrological conditions into its lower reaches. Especially during summer, the observed increment of the size of shoals downstream of Calcutta, therefore, has to be explained by a mechanism of tidal-tow of estuarine sediments produced by scouring of the floor of the shallow continental shelf at the base of the Bengal delta. This fact is, then, proven.

A SOCIAL COST ACCOUNTING OF THE FARAKKA SCHEME

The Farakka Barrage Project has been accepted as a major solution of the problem of keeping the seaward approach of Calcutta Port free of shoals. Keeping the other sections of the river navigable for country-boats is another subordinate objective.

The barrage site has been chosen at Farakka on the Padma, which has never been associated historically with any of the off-take points of the Bhagirathi. Consequently, a thirty-mile canal will bring water into the Bhagirathi at a point north of Jangipur town. This canal is designed to bring in 20,000 to 40,000 cusecs of silt-free water. In order that no part of this water flows back into the Ganga through the Giria off-take point, a barrage will be constructed at Jangipur. The Bhagirathi channel from Jangipur to Tribeni will be left as it is now with a few resectioning of a few existing shoals. At Tribeni, however, a substantial amount of water will be taken out of the Bhagirathi and will be poured into the now moribund channel of the Saraswati. This will ensure that the volume of discharge through the Bhagirathi from Tribeni to Uluberia remains as it is today. But below Uluberia, the discharges along the Saraswati and the Bhagirathi shall merge together. This combined discharge is expected to wash away the shoals of the sea bound channel of the Port of Calcutta.

The whole Project appears to us as a unique gambit of unmitigated opportunism. We propose to lay bare the principal components of our anxiety.

First, the construction of the barrage at Jangipur shall not only stop surface flow of water towards Giria but also the natural seepage flow of water that the region received normally. At least this is what the designers have planned to do. This means that the terrain between Jangipur and Giria shall be required to concede to the planned deprivation of social benefits of the Farakka Project and in addition to give up its natural rights upon the seepage flow.

Secondly, the section between Jangipur and Tribeni, after receiving 40,000 cusecs of additional discharge, will experience reshaping of the channel by natural hydraulics of valley widening. If we take into account the enormous amount of silts carried by the right-bank tributaries like Bansloi, Pagla, Dwarka, Mor, Babla, Ajay, etc., in this section into the Bhagirathi, predictions on the nature of reshaping of the channel will be anybody's guess. The magnitude of the silt bearing capacity of the Ajay may be estimated from the fact that in 1959 an area of about two square miles in Agradwip P. S. got covered by five to six feet thick sands in a single flood (Basu, 1967). Excepting the Mor, all these right bank tributaries have received no kind of river training. However, it may not be difficult to predict that resectioning of the shoals and riveting of the banks in this section of the river shall become a permanent programme. This shall permit continuous wastage of national savings and, of course, promotional activities of the regional and sub-regional political elites.

Thirdly, the idea of diverting water through the Saraswati, in view of the project design of the preceding section, is indeed a classic example of sardonic humour. The Hooghli-industrial-urbanized tract will not be required to face any hazard arising from similar increment of discharge through the Bhagirathi. The obverse side of this assurance is that all the shoals, like that of Halisahar, Ghusuri, etc., will persist right in the middle of the Hooghly industrial region thwarting navigation between the different towns and cities of the region.

Fourthly, in the section below Uluberia there will certainly be some increment of strength of the river to wash down the marine-estuarine silts. But how strong this discharge would be compared to the pressure of the tides is still unknown. The best estimate of the situation indicate that during low tide the river will have to wash away all the silts down its length of about one hundred miles into the sea in order to be effective. As this task is well nigh impossible to achieve, the more likely consequence would be more intensive chocking of the channel, for then the total load of marine estuarine silt will be contained within a shorter channel section than it is today. There will be more raised shoals on more extensive a scale. And the remedy shall come through permanent requisition of services for dredging and resectioning of shoals with perhaps greater heroism than what the Calcutta Port Commissioners had been doing over the last one hundred and thirty years or so. Heroism has dividends to offer, always !

Finally, the intensification of channel-choking in the section below Uluberia will cause serious upsets in the adjoining rural tracts. This region, we may remember, had been pre-maturely reclaimed through constructions of earthen embankments and the unit-cost of such reclamation was small because the river itself was in moribund state. The inflow from the Farakka Barrage is certainly going to enliven the channel to some extent and to increase the cost of maintaining the infrastructure of embankments correspondingly. In sum, the social cost of the Project shall be against this terrain. This is the way that contingent speculation perpetuates itself.

A POSTSCRIPT

We assure that we are not proposing to ditch the Farakka Barrage Project. On the contrary, we only wish to claim that adaptation of nature is like playing a musical instrument that has many strings. If one string is plucked the others vibrate, and the resonance so produced sings the glory of human civilisation. If we wish to resuscitate the Bhagirathi, then let us do it in a civilised way by first understanding the source of its ailment and then by helping it overcome the malady in the way it is capable of doing. We cannot let the ravages of soil-erosion go unabated in all the thalwegs of the right bank tributaries while expecting the Bhagirathi to clear the load. Why can't we expect a larger discharge from the Farakka barrage, or resectioning of the channel from Jangipur to Tribeni, or release of some water from Jangipur to Giria, or all these together and canalise the river as the son of Raja Saugor did once ?

REFERENCES

Ascoli, F.D., (1910) : *The Rivers of the Delta*: Asiatic Society, Bengal. Journal & Proceedings, Vol. VI, No. 10, p. 543-556.

Bentley, C.A., (1925) : *Malaria and Agriculture in Bengal*, Bengal Secretariat Book Depot., Calcutta.

Bhattasali, N.K., (1941) : *Antiquity of the Lower Ganges and its Courses* : Science and Culture.

Bagchi, Kanangopal, (1944) : *The Ganges Delta* : Calcutta University Press, Calcutta, 157, p.

Basu, Subhashranjan, (1967) : *Fundamental Problems of Meander Formation with special reference to the Bhagirathi River* : Indian Journal of Power and River Valley Development, Vol, XVII, No. 2, p. 15-23.

— (1967) ; *On some aspects of Fluvial Dynamics of River Bhagirathi with special reference to its physical and hydraulic characteristics* : I. J. of P. & R. V. Development, Vol. XVII, No. 6, p. 32-42.

— (1967) : *A quantitative Analysis of Silt Behaviour of the River Bhagirathi* : I. J. of P. & R. V. Development, Vol. XVII, No. 11, p. 15-22.

— (1967) : *A Critical Review of the Farakka Barrage Project* : Vishwakarma, Vol. VIII, No. 7, p. 30-34.

Basu, Subhashranjan, and Kar, Nishith Ranjan, (1970) : *Meandering, Migration and Alluvial Terraces in Lower Bhagirathi Valley, West Bengal, India* : I. J. of P. & R. V. Development, Vol. XX, No. 1, p. 29-39.

Bose, N. K., (1948) : *The Annual Report of the River Research Institute, West Bengal*, West Bengal Government Press, No. 4, 83, p.

— (1970) : *Rivers of West Bengal and their Control* : 'West Bengal', A Publication of the Geographical Institute. Presidency College, Calcutta, p. 59-65.

Chakraborty, S., (1965) : Pascim Vanga-pariciti, *Amrita* (Bengali weekly), 24 December, 1965, Vol. 5, No. 33, p. 575-580.

— (1970) : *Some Consideration on the Evolution of Physiography of Bengal* : 'West Bengal', A Publication of the Geographical Institute, Presidency College, Calcutta, p. 16-29.

Colebrooke, Major R. H., (1903) : *On the Course of the Ganges through Bengal* : Asiatik Researches, Vol. 7, p. 1-32.

Das, B. C , and Mukherjee, B. N., (1966): *Intermediate Dynamics* : Eleventh Edition, Ch. XII, p. 202-206.

Fergusson, J., (1863) ; *Delta of the Ganges* ; Geological Soc. London, Quart. Journal, Vol. XIX., p. 321-354.

Hayden, H. H., and Pascoe, E. H., (1919) : *Report on the Hooghly River and its head waters* : The Bengal Secretariat Book Depot, Vol. 1, App. 1, Calcutta. p. 17-21,

Hirst, Major F. C., (1916) : *Report on the Nadia Rivers 1915* : The Bengal Secretariat Book Depot, Calcutta, p, 39.

Hunter, W. W., (1875) : *A statistical account of Bengal* : Trubner and Co., London, Vol. 1, p. 22-34, 285-289.

Krishnan, M. S., (1953) : *The structural and tectonic History of India* : Geological Survey of India. Mem., Vol. 81, 109, p.

Majumdar, S. C., (1942) : *Rivers of the Bengal Delta* : Calcutta University Press, Calcutta, 124, p.

Mukherjee, Radhakamal, (1938) : *The Changing Face of Bengal—study in riverine economy* : Calcutta University Press, Calcutta, 288, p.

Morgan, James P and McIntire, William G. (1959) : *Quaternary Geology of the Bengal Basin, East Pakistan and India* : Bull. Geol. Soc Amr , Vol. 70, p, 319-342,

Oldham, Thomas, et al. (1859) : *On the Geological structure and physical features of the districts of Bancoorah, Midnapore and Orissa—Bengal* : Geological Survey of India. Mem., Vol. 1, p. 249-279.

Rennell, Tames J., (1781) : *The Ganges and Brahmaputra rivers* : Royal Society London Philos. Trans Vol. LXXI, p. 91-103.

Rennell, Tames J., (1793) : *An account of the Ganges and Burampooter rivers,* Appendix to Memoir of a map of Hindoosthan or the Mogul Empire : W. Bulmer and Co., London, p. 336-364.

Spate, O. H. K., and Learmonth, A. T. A., (1967) : *India and Pakistan,—A general and regional geography* : 3rd edition, Methuen and Co., London. 877, p.

Saha, J., (1966) : *The Study of texture and structure of the Hooghly Sediments between Katwa and Bandel, West Bengal,* unpublished M Sc., Thesis, University of Calcutta, Calcutta.

Sengupta, Supriya. (1966) : *Geological and Geophysical studies in Western part of Bengal Basin, India* : Bull. Amer. Asoc., Petrol Geologists, Vol. 50, p. 1001-1017.

— (1970) : *Geology of South Western Bengal* : 'West Bengal', A Publication of the Geographical Institute, Presidency College, Calcutta, p. 1-6.

Vredenburg, E., (1908) : *The Geological history of the Alluvial plain of Bengal* : Hemchandra Memorial Series, Part I, p. 24-59.

Wadia, D. N., (1949) : *Geology of India* : 2nd Edition Macmillan and Co., Ltd., London, 460, p.

West, W. D., (1949) : *Geological map of India* : Indian Geological Survey Records, Vol. 81, pt. I, p. 222.

Willcocks, Sir William, (1930) : *Lectures on the Ancient system of irrigation in Bengal and its application to modern problems* : University of Calcutta, Calcutta University Press, Calcutta. 128, p.

Editor's Note

Authors have referred to Bagchi (Page 62, line 1, column 1) mentioning that "whole of undivided Bengal is a part of this delta". This does not seem to be correct in view of his observation :

"... deltaic features are restricted in Bengal to the tract of the country south of the Ganges (Padma), between the Bhagirathi on the west and the Meghna (combined waters of the Ganges and the Meghna river) on the east. So that this portion is the only deltaic region in Bengal". *The Ganges Delta,* page 35 lines 12 to 19. This is in agreement with the contention of the authors—Editor.

DRAINAGE PROBLEMS OF THE BHAGIRATHI BASIN

K. D. CHATTERJEE
&
N. G. MAJUMDAR

Abstract

The object of this paper is to discuss the existing drainage pattern in the Bhagirathi basin and how the pattern is likely to be modified in the post-Farakka Barrage period.

A short description of the Bhagirathi-Hooghly system of rivers together with its tributaries has been given. The deterioration of the Bhagirathi-Hooghly system has been described in brief. The existing drainage pattern in the Bhagirathi basin has been described. How this drainage pattern is likely to be modified during the post-monsoon period when the discharge through the Farakka Barrage Feeder Canal is available has been discussed in some details. Possible modifications in the existing drainage pattern in the post Farakka Barrage period have been indicated.

The river Bhagirathi takes off on the right bank of the river Ganga in the district of Murshidabad and after traversing a distance of 350 miles falls into the Bay of Bengal. The non-tidal part of the river extending from the off-take to Nabadwip, a distance of about 150 miles, is known as the Bhagirathi while the tidal reach from Nabadwip to the Bay, a length of about 200 miles, is known as the Hooghly. The left bank tributaries of the Bhagirathi are the Bhairab, the Jalangi and the Mathabhanga. These three rivers are referred to as the Nadia rivers. There is only one significant tributary of the Hooghly on the left bank viz. the Churni which joins the river at Hanskhali. The right bank tributaries of the Bhagirathi are Bansloi, Pagla, Babla and Ajoy while those of the Hooghly are Damodar, Rupnarayan and Haldi. Thus the Bhagirathi-Hooghly system together with its tributaries accounts for by far the major part of the natural waterways of West Bengal. (Map at the end).

DETERIORATION OF THE RIVER SYSTEM

There are reasons to believe that until the 12th. century A.D. the main flow of the Ganga used to pass down the Bhagirathi channel. Then as a result of geomorphological processes which we have not yet been able to decipher fully, the main course of the Ganga started shifting towards Padma and by the 16th. century, the Padma became firmly established as the main course of the Ganga leaving the Bhagirathi as a spill channel. From 16th. century onwards, the Bhagirathi-Hooghly system is supposed to have undergone steady deterioration.

Quantitative assessment of the rate and extent of this deterioration is not possible for want of adequate data. We can only form a plausible picture of the process of deterioration. With the shifting of the main course of the Ganga into the Padma channel, the discharge through the Bhagirathi channel became inadequate to maintain it in regime. There was a marked drop in the velocity as the silt-laden water at high stages of the Ganga spilled into the Bhagirathi channel, which resulted in deposition of huge quantity of the silt in the head reaches of the Bhagirathi. The progressive deterioration of the off-take in its turn curtailed the headwater supply to the Bhagirathi which resulted in the deterioration of the lower reaches This process of deterioration must have been accelerated by human interference. Whenever the river had shrunk or had thrown up shoals, people promptly reclaimed these lands, sometimes prematurely by putting up embankments which had interfered with the natural activities of the river. The actual process must have been very much more complicated. The discharge and silt charge through the western tributaries must have played a significant part.

Be that as it may, the present position is that at the maximum stage the Bhagirathi draws about 4% of the Ganga discharge.

It is however, very difficult to establish definitely from available records that the Bhagirathi has either improved or deteriorated. On the other hand it is an admitted fact that navigability of ocean liners from the sea to the Calcutta Port is suffering for want of requisite navigable depths. It is equally true that the Jalangi is dead, the Bhairab and the Mathabhanga are moribund and that a large number of swamps have developed in the Bhagirathi-Hooghly basin having insufficient drainage potentialities.

EXISTING DRAINAGE PATTERN IN THE BHAGIRATHI BASIN

Left Bank drainage basins

This area may be considered to be bound by Bhagirathi on the west, Ganga in the east and Bhairab-Jalangi on the south. This left bank drainage basin may be conveniently divided into the following sub-areas.

(i) The area below Jangipur between the Padma on the East, Bhagirathi on the west and Ganga-Bhagirathi embankment on the south, has two drainage basins :

(a) Suhas Bil—5 sq. miles.

(b) Krishnasali Bil—8 sq. miles.

These basins drain directly into the Bhagirathi the rainfall of the local catchment. The spills from the Padma at high stages also find passage into these low areas and ultimately drain into the Bhagirathi when its level goes down.

(ii) The area enclosed within the Ganga-Bhagirathi embankment, the Bhagirathi embankment and the Bhagirathi on its left bank upto Jiaganj has the following drainage basins :

(a) Ramghat Drainage channel basin—3 sq. miles.

(b) Basantapur Drainage channel basin—1 sq. mile.

(c) Rajanagar Laltakuri Drainage channel—3 sq. miles.

iii) From Jiaganj to Metiary in P. S. Kaliganj of Nadia District, a very long reach of the Bhagirathi is embanked as the left bank. The small sluices in this embankment practically serve irrigation purpose. No significant drainage into the Bhagirathi is effected in this reach.

iv) Below Metiary upto Swarupganj, the area close to the Bhagirathi has abandoned loops of the river and low areas. These drain into the Bhagirathi as follows :

(a) Stewart khal basin—4 sq. miles.

(b) Bager khal basin—6 sq. miles.

(c) Dead loop basin—14 sq. miles.

(d) Gurguria khal basin—6 sq. miles.

(e) Kanchkuli khal basin—3 sq. miles.

(f) Bamanpukur Bil—1 sq. mile.

A part of this area drains into the Jalangi.

Right Bank Drainage Basins

The right bank tributaries of the Bhagirathi are (1) Bansloi, (2) Pagla, (3) Jhumjhumkhali, (4) Uttarasan (5) Babla (6) Ajoy.

The Bansloi and Pagla fall into the Bhagirathi above Jangipur town. These rivers intercept criss-cross drainage channels of complicated geometry of the terrain lying between the Santhal Pargana hills on the west, the spills from the Ganga and the backflow from the Bhagirathi on the east.

The area on the right bank of the Bhagirathi below Jangipur upto the outfall of the Babla near Katwa intercept the drainage of the entire Mayurakshi system of rivers and local stormbursts and drains into the Bhagirathi through the Babla near Katwa. There is a large scale flood retention reservoir in this area viz. the Hizol bil. The drainage of the Mayurakshi basin gathers in this bil and ultimately passes into the Babla which traverses a distance of about 25 miles from the bil to fall into the Bhagirathi above Katwa. Uttarasan is a bifurcation of the Babla which falls into the Bhagirathi by traversing a comparatively shorter distance of 10 miles. The Jhumjhumkhali falls into the Bhagirathi just downstream of Berhampur and serves as a secondary drainage channel of the Kandi area. The Ajoy which falls into the Bhagirathi at Katwa has a steeper bed slope and has no significant drainage basin in its tail reaches.

The above few paragraphs give a short description of the drainage basins and different drainage channels on both sides of the Bhagirathi. The efficiency of the Bhagirathi channel as a flood carrier is very low at the present moment. Different tributaries on both banks are in different stages of decay. Hence during the flood season when the Bhagirathi level is high, any spell of sustained rainfall results in drainage congestion in the Bhagirathi basin. Formerly, the Hizol bil used to act as a flood moderator for a large tract of the right bank basin. But Hizol bil is being gradually reclaimed which is encroaching upon its flood retention capacity. This is aggravating the drainage problem of the entire area between the outfall of the Pagla and that of the Babla.

In the background of the conditions as stated above 20 drainage schemes have already been executed in the district of Murshidabad as given in the Appendix-3. The execution of these schemes has given immense benefit and the low areas have been practically reclaimed.

THE FARAKKA BARRAGE PROJECT

The above is a short description of the existing drainage pattern in the Bhagirathi basin. A new element is going to be introduced which is likely to modify this pattern quite significantly and as such would deserve very careful consideration.

As has already been stated above, the Bhagirathi-Hooghly system is showing signs of progressive deterioration. This is threatening the existence of Calcutta as a major port. Hence a scheme for the preservation of the Port of Calcutta has been drawn up and is at present under execution. This scheme envisages the construction of (1) a barrage across the river Ganga at Farakka ; (2) a barrage across the Bhagirathi at a place about 4 miles upstream of the Jangipur town, and (3) a feeder canal taking off from the Ganga upstream of the Farakka Barrage and falling into the Bhagirathi downstream of the Jangipur barrage. The feeder canal is designed for a discharge of 40,000 cusecs.

The object of the project is (1) to even out the flood hydrograph at Kalna during the freshet season ; (2) to supply a flushing dose of 40 thousand cusecs through the feeder canal during the non-freshet season.

It has been found by intensive study that a flood discharge of 120,000 cusecs at Kalna for as long a period as possible during the freshet season would be very beneficial to the Port of Calcutta. All attempts would be made to prolong this flood discharge at Kalna as far as possible by combined operation of the feeder canal and Jangipur barrage during the freshet season. This, together with a steady flushing dose of 40 thousand cusecs during the non-freshet season, is likely to improve the channel from Calcutta to the sea to the desired extent. It is also expected to increase the efficiency of the entire Bhagirathi-Hooghly system as a drainage carrier. In this connection some corrective measures at different reaches of the Bhagirathi-Hooghly are also under consideration.

In this paper we are, however, concerned with the effect of the Project on the existing drainage pattern in the Bhagirathi basin and we proceed to consider the point.

FLOOD-SEASON DRAINAGE IN THE POST-FARAKKA BARRAGE PERIOD

After the execution of the Project, there will be complete control over the discharge through the Biswanathpur head. This would undoubtedly ease the drainage problem in the Bhagirathi basin during the freshet season. Again, when the Bhagirathi-Hooghly attains regime under the post-Farakka barrage condition, its efficiency as drainage carrier is likely to increase considerably. In that case, the monsoon drainage position in this area is likely to ease further.

PRE- AND POST-MONSOON DRAINAGE UNDER POST-FARÂKKA BARRAGE CONDITION

At present there is headwater supply to the Bhagirathi only for about 5 rainy months in a year. For the remaining 7 months the off-take from the Ganga is masked and only seepage flow is available varying from 6 inches to 1 ft. in depth. Under the post-Farakka Barrage condition, the Bhagirathi will receive about 40 thousand cusecs discharge from the Ganga through the feeder canal even in dry months at about 4 miles up-stream of Jangipur town.

We now proceed to investigate the effects of this additional discharge of 40 thousand cusecs through the Bhagirathi during the dry period on the drainage basin of the Bhagirathi. The effects may be summarised as under :

1. In the pre-monsoon period when aus and jute seedlings are tender or aman cultivation is started with a few local storm brusts, water of the Bhagirathi will find its way through the existing drainage channels or through natural depressions and may submerge the low basins. This will create difficulties to the cultivators.

2. At the beginning of the *kharif* harvesting season, the water from the low areas are drained into the Bhagirathi. This takes place in the period from end of October to end of November. During this period the water levels in the Bhagirathi goes down very rapidly and practically touches the dry weather stage. Now if an additional 40 thousand cusecs discharge passes through the Bhagirathi at this period, there will be drainage congestion in the low areas and cultivators will not be able to harvest *kharif* crops and replant for *rabi*.

We now proceed to assess the extent of congestion that is likely to be caused by this additional 40 thousand cusecs discharge during the dry months. The following assessment is based on the present stage-discharge relation obtaining in different reaches of the Bhagirathi. It may be pointed out that after the Bhagirathi attains regime under the post-Farakka Barrage condition, the levels indicated below at different reaches for a discharge of 40 thousand cusecs will be somewhat lower partly due to retrogression and partly due to execution of schemes for increasing the efficiency of the Bhagirathi channel. However, the condition obtaining during the first few years after the commissioning of the Farakka Barrage will be very much the same as indicated below.

Gauge discharge observations are available at Jangipur and Purbasthali. These data have been used in the following studies.

The post-monsoon drainage period under the post-Farakka Barrage condition has been considered to be from the end of October to the middle of November. As such the stage discharge relationship of the Bhagirathi for the above sites has been considered for 7th November each year for 6 years. On 7th November some seepage flow is available at the above sites. The stages of the Bhagirathi with this available discharge increased by 40 thousand cusecs discharge from the feeder canal have also been determined for the above sites for the same year. These stages corresponding to these total discharges are naturally available in the flood season.

From a perusal of the appendixes 1 & 2, it will be evident that the Bhagirathi will rule about 15 ft. higher on an average at Jangipur and about 11 ft. higher on an average at Purbasthali on 7th November at the thick of the post-monsoon drainage period. The same heading up may also be taken for all practical purposes during the early monsoon period.

We have already enumerated the different drainage basins which drain directly into the Bhagirathi which will be affected by this increase in the level of the river during the pre- and post-monsoon periods. To these we have to add the drainage basins that drain into the Jalangi. In this connection we have to consider what length of the Jalangi will have back water effect due to rise in the level of the Bhagirathi at Swarupganj. Considering the decrease in the effect of the additional 40 thousand cusecs discharge on the ruling level of the Bhagirathi from Jangipur to Purbasthali and the fact that Swarupganj is at the tidal head, the heading up at Swarupganj may be taken to be 9 ft. Taking the water surface slope in Jalangi as 0.3 ft. per mile, a length of 30 miles of the river will be affected. It is fortunate that the Jalangi, which intercepts the drainage of a major portion of Murshidabad and Nadia districts, has most of the drainage basins above the said reach. Hence only the following drainage basins need be considered.

(a) Nandandanga Bil	—	1 sq. mile
(b) Chulkuri Bil	—	1 ,,
(c) Arangsarisa Bil	—	10 sq. miles

The position of the drainage basins on the right bank would also be somewhat similar. The effect of heading up in the Bhagirathi will travel up the right bank tributaries. The lengths of the different tributaries that would be affected by this heading up will obviously depend upon water surface slopes in these tributaries. The drainage basins falling within the affected reach will suffer from drainage congestion.

PROBABLE REMEDIAL MEASURES

We have tried to give a brief sketch of the problem of pre- and post-monsoon drainage in the Bhagirathi basin under the post-Farakka Barrage condition. One point that has to be stressed in this connection is that this flushing dose of 40 thousand cusecs during the dry months is a must for the Port of Calcutta. So we shall have to live with any problem that may be created by it and try to solve the same as best as we can. One of the objects of this paper is to draw the attention of the engineering elite to this problem so that they may put their heads together to evolve a workable solution. A few are offered below for consideration.

(1) An initial regrading of the Bhagirathi-Hooghly which would enable it to attain regime quickly under the post-Farakka Barrage condition. As we have already mentioned, when this regime is established heading up due to the additional discharge of 40 thousand cusecs would be somewhat less and the drainage congestion in the Bhagirathi basin would be relieved to that extent.

(2) It may be necessary to construct

drainage sluices at the outfall of some of the drainage channels. This would prevent the backing up of the Bhagirathi water into these drainage channels. Obviously, these sluices must be able to cater for the maximum discharges of the respective channels. In case of the Babla which drains the entire Mayurakshi basin, the sluice may have to be designed for a discharge of 0 2 million cusecs. This would be a very costly affair.

(3) Increasing the slope of the river and improving the stage-discharge relation by artifical cut-offs.

This improvement of slope may possibly be attained by artifical cut-off of the following loops of the Bhagirathi.

Reach	Length of the loop in miles.	Length of cut in miles.	Shortening in miles effected by the cut.
1. Nutanganj to Kismal Godi	5½	1¾	3¾
2. Mathurapur to Dasturhat	7	1½	5½
3. Halalpur to Chowrigacha	3	¾	2¼
4. Simuldanga to Saktipur	3	½	2½
5 Kalikapur to Agradwip	10¾	1¼	9½
6. Santoshpur to Nanpur	7¼	2	5¼
7. Cutsali to Mayapur	6¾	1¼	5½
	43¼ miles	9 miles	34¼ miles.

This shortening of the river length by 34¼ miles would increase the slope proportionately. This would increase the discharging capacity of the channel and would consequently improve the stage discharge relationship of the river. In other words, this river will pass the same discharge at a lower level.

As this suggestions is very tempting, a word of caution is indicated. Cutting off of loops interferes very seriously with the regime of a river and the river may have the tendency to regain its length and regime by developing meanders elsewhere. This may have unforeseeable consequences. In any case, any concrete suggestion for cutting off of loops should be considered only when all its consequences have been thoroughly investigated from all possible angles. In this connection, we may mention that shortening of river length by artificial cut offs has been successfully effected in the case of the Mississippi.

CONCLUSION

In the foregoing paragraphs we have tried to trace the deterioration of the Bhagirathi-Hooghly Channel which upto the 12th century was the main course of the Ganga but is now only a spill channel receiving head water supply only during the monsoon months. The present flood carrying capacity of this channel is very low any spell of sustained rainfall results in drainage congestion of the Bhagirathi basin. A short description of the drainage basins on both banks of the Bhagirathi has been given. During the post monsoon period the levels of the Bhagirathi falls very rapidly and the water accumulated in the drainage basins are quickly drained. With the commissioning of the Farakka Barrage Project the efficiency of the Bhagirathi-Hooghly channel is expected to increase considerably thereby relieving the drainage congestion in the Bhagirathi basin during the monsoon months. But the additional discharge of 40 thousand cusecs through the feeder canal of the Farakka Barrage is likely to create drainage problem in the pre- and post-monsoon period. As a result of this additional discharge the Bhagirathi levels at Jangipur, Purbasthali and Swarupganj will rule about 15 ft., 11 ft. and 9 ft. higher respectively than at present and this will interfere with the existing pre- and post-monsoon drainage pattern.

It has been suggested that after the Bhagirathi has attained regime under the post-Farakka Barrage conditions, the present level of Bhagirathi corresponding to any particular discharge is likely to go down and the above figures of 15 ft., 11 ft. and 9 ft. may be considerably less. This would relieve the drainage congestion in the pre- and post-monsoon period to some extent. It would therefore be desirable to help the Bhagirathi attain regime under the post-Farakka Barrage condition by some initial dredging. It has also been suggested that suitable drainage sluices may have to be constructed at the outfall of the main drainage channels on both banks of the Bhagirathi.

APPENDIX—1

Jangipore Site

The Post-monsoon drainage period has been considered from end of October to middle of November. As such the present stage of Bhagirathi with the available discharge has been considered for 7th November each year. When the feeder canal supplies 40,000 cusecs, the stage of the Bhagirathi rises due to the increased discharge (Post-monsoon available discharge on 7th November 40,000 cusecs). The stage obtainable with their total discharge has been derived from a near

Date. 1	Discharge in cusecs. 2	Gauge in Ft. (GTS) 3	Date 4	Discharge in cusecs. 5	Gauge in ft. (GTS) 6	Difference in stage. (6—3)
7.11.63	4,103	49.36	16.9.63	43,746	63.83	14.47
7.11.64	155	46.68	19 9.64	40,702	63.42	16.74
7.11 65	156	45.02	13.9.65	43,436	62.32	18.30
7.11.67	Nil	48.11	11.8.67	40,735	60.99	12.88
7.11.68	77	48.49	31.8.68	40,319	64.51	16.02
					Average :	15.68 ft.

about value available during monsoon months.

The stage at Bhagirathi will be about 15.68 ft. higher on average than what is available at present during post-monsoon drainage period if 40,000 cusecs discharge is fed into the Bhagirathi by the feeder Canal.

APPENDIX- 2

Purbasthali site

The post-monsoon drainage period has been considered from end of October to middle of November. As such the present stage of Bhagirathi with the available discharge has been considered for 7th November each year. When the feeder canal supplied 40,000 cusecs, the stage of the Bhagirathi rises due to the increased discharge (Post monsoon available discharge on 7th November plus 40,000 cusecs). The stage obtainable with their total discharge has been derived from a near about value available during monsoon months.

The stage at Bhagirathi will be about 11.55 ft. higher on average than what is available at present during post-monsoon drainage period if 40,000 cusecs discharge is fed into the Bhagirathi by the feeder canal.

Date 1	Discharge in cusecs. 2	Gauge in ft. (GTS) 3	Date 4	Discharge in cusecs. 5	Gauge in ft. (GTS) 6	Difference in stage (6—3)
7.11.63	17,346	16.48	14.9.63	57,488	25.19	8.71
7.11.64	600	11.79	19.9.64	47,787	23.90	12.11
6.11.65	3,348	9.32	28.9.65	43,654	22.44	13.12
7.11.66	2,324	8.17	8.8.66	42,576	21.51	13,34
7.11.67	3,515	10.04	11.8.67	47,370	23.04	13.00
7.11.68	4,633	11.19	27.6.68	44,707	20.23	9.04
					Average :	11.55 ft.

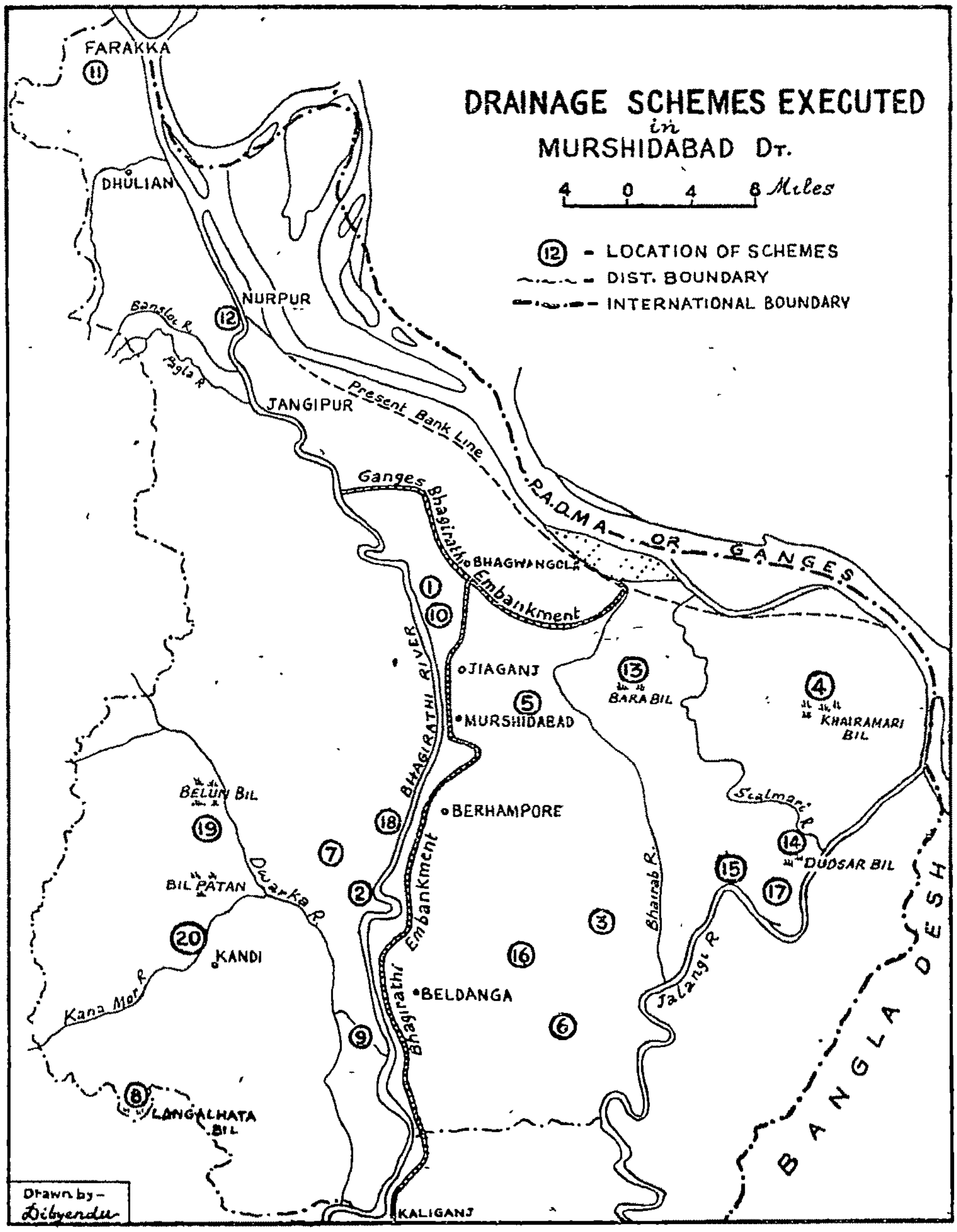


Figure indicating location of schemes
in Appendix—3.

APPENDIX—3

Showing the Minor Drainage Schemes already executed in the Murshidabad district.

Sl. No. 1.	Name of schemes. 2.	District. 3.	Thana 4.	Benefited area. 5.
1.	Rajanagore Laltakuri Drainage Channel	Murshidabad	Lalgola	3 sq miles.
2.	Chowti Bil Drainage Channel	,,	Berhampur	500 acres.
3.	Bengdaha Bil Drainage Channel	,,	Hariharpara	2,000 ,,
4.	Khairamari Bil Drainage Channel	,,	Donkal and Jalangi	2,000 ,,
5.	Gobranullah Cut	,,	Bhagwangola	1,700 ,,
6.	Kodalkati Kata Khal Scheme	,,	Nowda	9,600 ,,
7.	Jibanti Banki Drainage Channel	,,	Nabagram Kandi	11 sq. miles
8.	Langalhata Bil Drainage Schemes	Murshidabad & Birbhum	Barwan & Labpur	5 ,,
9.	Drainage of Gora Bil Schemes	Murshidabad	Kandi	280 acres.
10.	Ramghat Drainage Channel	,,	Jiaganj & Bhagwangola	3 sq. miles
11.	Sahebanagore Trimohini Drainage Channel	,,	Farakka	4.5 ,,
12.	Chowani Bil Drainage Channel	,,	Suti	155 ,,
13.	Bara Bila Bil Drainage Channel	,,	Raninagar	260 ,,
14.	Dudsar Bil Drainage Channel	,,	Domkal	1,280 acres.
15.	Sultanpur Bil Drainage Channel	,,	Domkal	640 ,,
16.	Pirtala Khal Drainage Channel	,	Nawda	2,240 ,,
17.	Kankra Zole Bil Drainage Channel	,,	Domkal	685 ,,
18.	Nal Bil Drainage Scheme	,,	Berhampore	6¾ sq. miles
19.	Drainage of Bil Belun, Patan and other Bil Drainage Scheme	,,	Khargram	Scheme in progress 10 sq. miles.
20.	Rameswarpur Drainage Scheme.	,,	Kandi	1 sq. mile.

SEDIMENT TRANSPORT CHARACTERISTICS IN THE HOOGHLY AND EFFECTS OF UPLAND DISCHARGE

A. K. CHAKRABARTI & A. SEN

Abstract

The paper describes broadly the flow condition of the Hooghly and sediment characteristics. The general nature of the sediment movement have been studied in conjunction with overall accretion and erosion pattern of the river and a new criterion has been developed to study the direction of drift of bed material load over a tide cycle.

The decay of the river Hooghly may be attributed to the inadequate transportation of sediment along the river.

The sediment movement is concomitant to the flow system which characterises the different stretches of the river. Hence at first, a brief introduction to the flow system has been given without any description of the geography of the river or its geomorphological evolution which can be found elsewhere.

Sediment movement pattern has been studied for the different reaches. The cause of deterioration of the upper tidal region due to redistribution has been explained and supported by the derived concept of sediment transport predominance.

For the lower Hooghly estuary, attempt has been made to explain the general behaviour of the sand movement from the observations and existing theories. Some of the material on which the conclusions are drawn have not been appended in the paper.

REGION STUDIED

The study concerns the Hooghly river from Swarupganj, which is close to the dry season upper tidal limit of the Bhagirathi-Hooghly system, to Saugor. This stretch of the river system is called the main Hooghly river (Map at the end).

It is a maritime river and is closely studied The river like all alluvial channels is a meandering one, with acute bends ; the bottom profile is complicated by shoals, sands, bars and crossings and over a greater portion of the river stretch, there exists two distinct thalwegs, one for the flood, the other for the ebb.

The investigations are restricted to the river channels only.

FLOW IN THE HOOGHLY

Behaviour of the boundary conditions

The flow in a tidal river is dominated by two boundary conditions, viz., the river currents, caused by the water coming down the channel on the landward side and the tidal currents, caused by tidal movement on the seaward side.

In the Hooghly the two boundary conditions do alter in time. The quantity of water coming down the river varies considerably in the course of a year. The head water flow is almost nil up to the last week or so of June and reaches a peak in September (order 150,000 cusecs) and again fall off almost to nothing by December.

Tidal currents too fluctuate in time, primarily as a consequence of the variation in the tidal amplitude. Besides the usual spring tide and neap tide variations, in the Bay of Bengal southerly breeze starts from about February onwards, reaches the peak in the monsoons and cease in winter months. As a result of this, the mean sea level at the sea face starts rising from about February and reaches a peak in September and falls back in winter months.[1] (Fig. 1).

The net result of the above changes is the appearance of weakest tide during winter months, more stronger tides between February and May and finally the strongest tide during perigee spring tide near equinox at September. That the amplitude of tide suffers a cyclic change within a year, will be revealed from Table—1 showing tidal characteristic at Saugor.

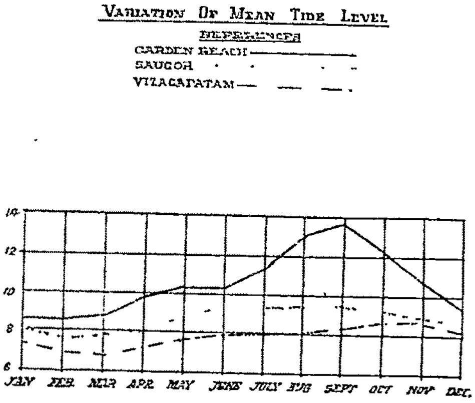


Fig. 1

Some idea of the variation in the strength of the currents at different sections of the reach under various upland discharges can be obtained from Fig. 2 based on the mathematical model data for the Hooghly.[2] It covers the reach most

TABLE—I

Tidal Characteristics at Saugor

Month	Mean Range in ft.	Mean low water	M.T.L.
January	9.95	5.03	10.60
February	9.78	4.80	9.69
March	10 45	4.39	9.62
April	10.60	4.49	9.79
May	10.48	4.95	10 19
June	10.34	5.62	10.99
July	10 20	5.72	10.82
August	10.50	5.77	11.02
September	10.60	5.80	11.10
October	10.71	5.72	11.07
November	10.55	5.57	10.84
December	10.00	5.33	10.33

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[1] Hydraulic Study Dept., Sp. Note No. 47.

[2] Hydraulic Study Dept., Sp. Note No. 43.

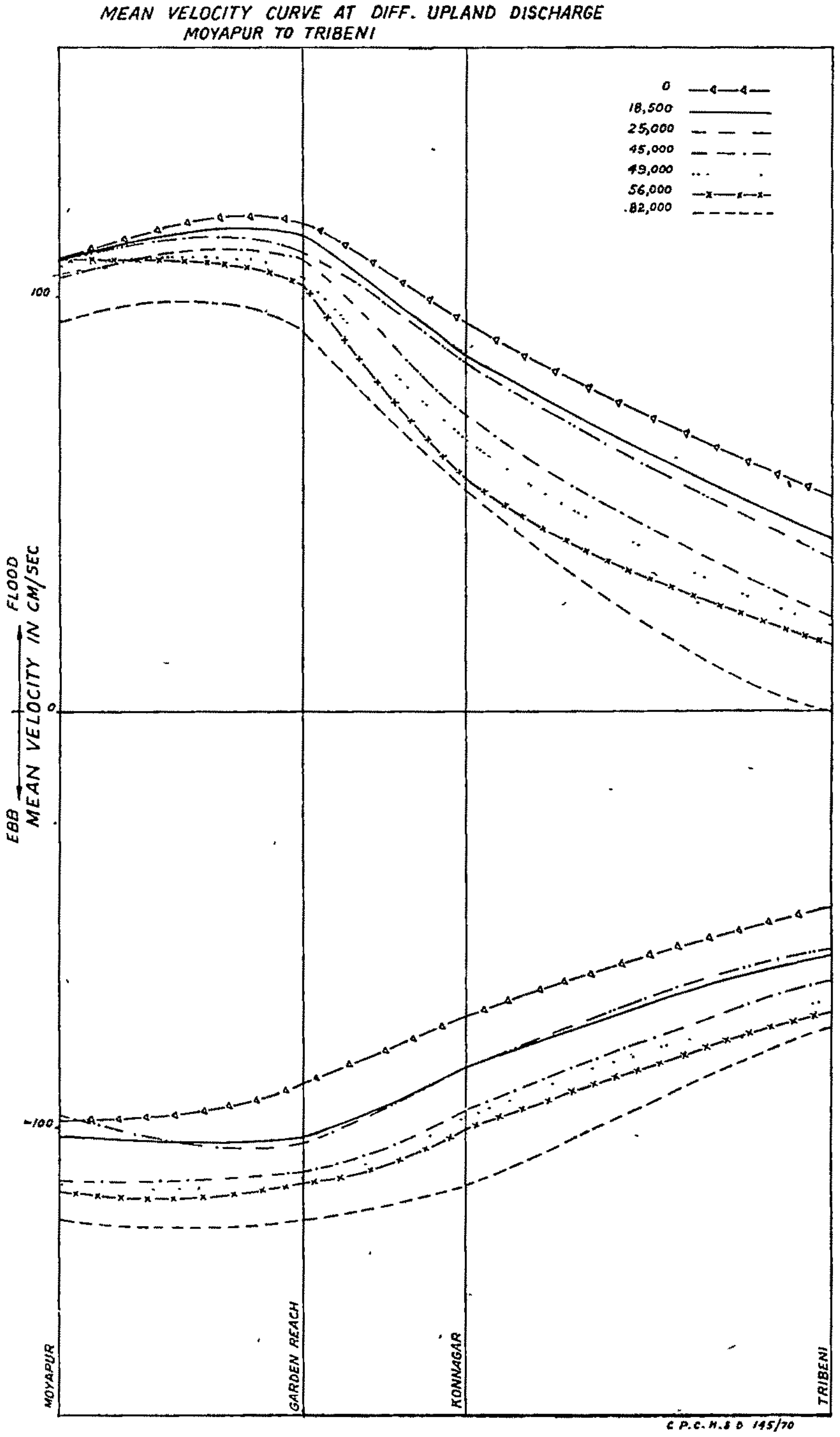
MEAN VELOCITY CURVE AT DIFF. UPLAND DISCHARGE
MOYAPUR TO TRIBENI
0
18,500
25,000
45,000
49,000
56,000
82,000
100
0
-100
EBB
FLOOD
MEAN VELOCITY IN CM/SEC
MOYAPUR
GARDEN REACH
KONNAGAR
TRIBENI
C.P.C.-H.S.D 145/70

Fig. 2

important for sediment transportation. Similarly the range of tidal influence during different upland discharge can be estimated. The behaviour of the mean current shows that the effect of moderately high upland discharge do not extend beyond Moyapur.

General flow pattern

In the dry season when there is no upland flow, the tidal limit is just beyond Swarupganj during tides, but in freshets it depends not only on the tides coming in from the sea but also on the fresh water supply from the Bhagirathi. The upland discharge pushes the tidal limit seawards and the actual location depends on the balance between the quantity of upland discharge and the tidal flux from the sea. Thus, when the upland discharge is of the order of 100,000 cusecs the upper tidal limit comes down to Tribeni for spring tides whereas for a neap tide it is still much further down.

EVALUATION OF SEDIMENT MOVEMENT IN THE HOOGHLY

In a tidal river the depth and the flow rate is changing and the bed is subject to shear that is not entirely in phase with the flow, the sediment transport is obviously more complicated than in uniform flow. A search for equations to connect the hydraulic variables to the sediment flow so far has not been successful. There are two standard procedures for assessing net drift of sediment. One of the approaches is to measure the concentrations of sediment at different depths, in different reaches of the river and at different phases of the tide and to measure simultaneously at each place the velocity and direction of current. These are carried out at discrete verticals. The integration of this data provided some information in regard to the locations where there is net upstream flow, locations where there is net downstream flow and where silting may be expected.

The other method is periodic surveys which revealed the residual effect of the sediment movement. They showed from variation in contour lines and capacity of the river stretches, the reaches having accretion, scouring and those maintaining themselves. Both of these methods are used for the study of the sediment transport in the Hooghly.

Improved mathematical models have now made possible derivation of instantaneous water levels and mean velocities as tide flows and ebbs. The velocities across a section thus obtained can be utilized to find the direction of the final sediment drift across the section. The method has been expressly developed for study of dry season redistribution of sediment in the Hooghly and given in detail below.

There has been in recent years the gradual emergence of flourescent and radio active tracers method for assessment of sediment movement in tidal estuaries and coastal water. The basic principle of tracer work is the seeding of a part of the bed with particles having the same hydraulic properties as the natural sediment but is marked in such a way as to permit their identification when present at low concentration amongst the natural bed grains. Surveys of the changing distribution of the labelled particles with time presents a dynamic picture of the drift and dispersion effects experienced by the moving sediment. Calcutta Port Commissioners have carried out some tracer studies to select suitable locations for dumping dredged spoils. The resources necessary for rapid tracking survey prevents Calcutta Port Commissioners from making more extensive use of the technique.

Concept of sediment transportation predominance

Much of the material which settle on river bed is that fraction of the sediment load which move along the bed. No purely theoretical approach to the general principles of sediment discharge in alluvial channel seems possible at present because of insufficient quantitative knowledge of fluid turbulence and its effect on sediment within the fluid. Hence the approaches to formulate for estimation of bed load discharges are either empirical or semi-theoretical and is based on existing theory of turbulent flow and on general ideas derived from observation and reliable speculation. For the latter group three well known derivations are due to Schields (1936), Kalinske (1947), and Einstein (1950).

Following derivations of Laursen (Roy, 1969), one finds for Schields and Kalinske's formulae $q_s \propto V^5$ and for Einstein's $q_s \propto V^6$ where q_s is the bed load transport per unit width and V is the flow velocity.

Most of the bed load formulae involve a term expressing the difference between the shear stress on bed and the critical shear for initiation of particle motion. The beginning of a particle motion is difficult to assess. The point of incipient motion is usually estimated visually and naturally the results obtained depend greatly on the particular observer. Einstein did not use the concept of critical shear stress. The implication of this is that some transport of material will occur at any flow velocity greater than zero. Einstein adopted this approach in order that difficulties and uncertainties mentioned above do not arise, and is expected to yield more consistent result. Thus, Einstein's formula based on probability theory and relying on experimental results for evaluation of the various constants and indices, is potentially superior to others. Moreover, a set or series of functionally correct diagrams as incorporated in Einstein's procedure, provide a more reliable starting point for extrapolative deduction than an equation which is derived from superficially compressing of experimental points into a narrow band covering a limited range of circumstances.

The actual field observations also confirmed that $q_s \propto V^6$ as derivable from Einstein's equation, is more compatible with the conditions found in the Hooghly.

Using the relation $q_s \propto V^6$ to extend the concept of predominance of water flow to the bed material flow, the net relative movement of material has been evaluated. The sixth power of instantaneous mean velocities, obtained from the mathematical model of the river based on measurements in nature and computation with the aid of a high speed digital computer for a tide, are plotted against time. The areas subtended by both flood and the ebb positions of the curves of the plot are plainimetered and total area thus determined provided an index to the total flow of bed material across the section. The areas subtended by the flood portion of the curve is then divided by the combined areas of the flood and ebb portions of the curve, the ratio is called the load transport predominance. Symbolically this can be expressed as

$$P_s = \frac{\int_0^{T_1} V_F^6 \, dt}{\int_0^{T_1} V_F^6 \, dt + \int_{T_1}^{T_2} V_E^6 \, dt}$$

where V_F is the flood velocity, V_E is the ebb velocity, T_1 and T_2 are times of high and low water slacks. Obviously for a tidal cycle, if P_s is greater than 0.50, the net transport of bed material is landwards and if P_s is less than 0.50, transport is seawards.

PATTERN OF SEDIMENT MOVEMENT IN THE HOOGHLY

In the River Hooghly during the freshets, the net drift of sediment carried by it, is seawards. While during the dry season, in the upper tidal reach of the Hooghly, due to much stronger flood currents, landward redistribution takes place. The dry season redistribution is in excess of the freshet improvement. Consequently, every year the capacity of the river channel over the upper stretches of the tidal reach, decreases progressively.

From the point of view of this accretion and scouring the Hooghly river can be divided into three stretches.

(i) Upper tidal compartment from Nabadwip to Cossipore, 77 nautical miles long.

(ii) From Cossipore to Diamond Harbour, 42 nautical miles long.

(iii) The estuary, south of Diamond Harbour.

(i) The dry season predominance of load transport capacity is revealed from Fig. 3. It shows that the relative transport capacity of flood flow is high up to Cossipore and then is gradually reduced.[3] Therefore, it is expected that considerable siltation in the upper reach beyond Cossipore will take place due to redistribution. This is borne out by the loss of capacity over the reach as the freshet flow fails to remove the redistributed load.

TABLE—2

Loss of Capacity (Swarupganj to Cossipore)

Datum	Reach	Year	Capacity in m.c. yds.	Total loss in m.c. yds.
Below	Nabadwip	1951	30.78	
LLW	to			2.77
level	Kalna	1963	20.81	
Below	Kalna	1951	66.60	
LLW	to			14.40
level	Bansbaria	1963	52,20	
10 ft.	Bansbaria	1951	203.99	
above	to			39.44
KODS	Cossipore	1963	164.55	
Datum				

(ii) Over the reach extending from Diamond Harbour to Cossipore, there is substantial predominance of load trans-

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[3] Hydraulic Study Dept., Sp. Note No. 45.

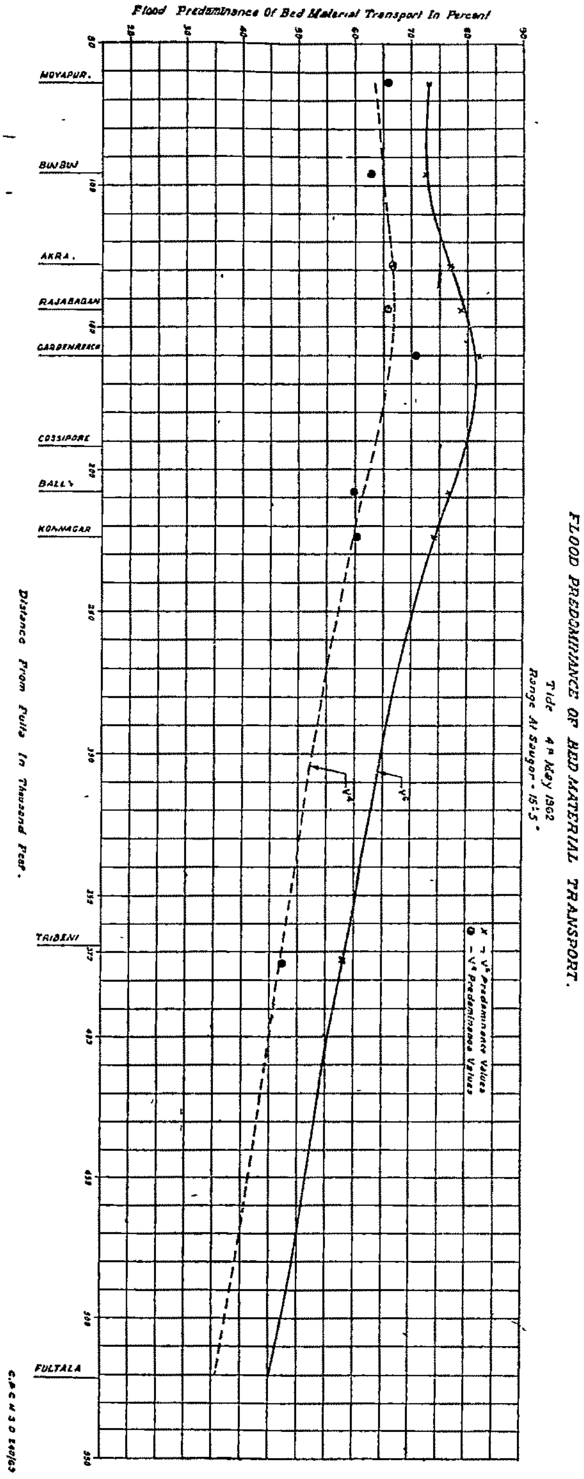
FLOOD PREDOMINANCE OF BED MATERIAL TRANSPORT.
Tide 4th May 1962
Range At Saugor - 15'.5"
x – V³ Predominance Values
⊕ – V⁴ Predominance Values
Flood Predominance Of Bed Material Transport In Percent
20
30
40
50
60
70
80
90
Distance From Fulta In Thousand Feet.
MOYAPUR.
BUDBUDI
AKRA.
RAJABAGAN
GARDENREACH
COSSIPORE
BALLY
KONNAGAR
TRIBENI
FULTALA
V⁴
V³
C.P.C.M.S.D. 240/63

Fig. 3

port during floods i.e., drift of materials is upstream. The accretion and scouring are governed by the sediment concentration in flood flow. When the flood flow enters the reach with sediment in suspension and load picked up from the bed over the lower estuary part of the Hooghly, it is fully charged to its transport capacity. Therefore, during dry months there is hardly any scouring, rather accretion takes place over bars and crossings over which there are local reduction in transport capacity. Also the ebb channels are silted up and the flood channels are scoured. This accretion is not completely removed by scouring during freshet flows whose effect is comparatively weaker over this reach due to larger tidal flow. However, the freshets open up the ebb channels and silt up the flood channels.

As this reach is navigated the local siltation over bars and crossings and seasonal silting up of channels form major problems. These local areas of siltation have to be artificially deepened. They form natural accretion areas for sand or silt driven along the adjacent points. Therefore, continuous maintenance dredging have to be done, which is apparently an unavoidable penalty for holding a channel below its natural depth. Both the post-freshet and pre-freshet capacity have a very irregular trend.[4]

(iii) Below Diamond Harbour the strength of ebb currents are almost as high as the flood currents. Therefore, the flood predominance during dry season is almost nullified. Unfortunately it has not been possible to extend the mathematical model to cover this reach so the reflections are based on the less accurate method of 'Cubature'.

The siltation and accretion over this reach is influenced by the orientation of ebb and flood channels, the wind, the sediment charge and the water volume brought down by the freshets, salinity intrusion and coriolis effect. Within the inner estuary of the Hooghly the ebb channels behave very similar to a normal mature river, they bring down the fluvial sediment to the sea-end where they loose their transporting power and deposit the material. These materials are redistributed by the flood currents and waves. The flood flows carry part of this material and deposit them further up inside the estuary forming shoals and sands at the upstream end of the flood channels. The ebb-flood pattern of channels, shoals and sands in the Hooghly estuary are seldom stable. Variations in the freshet volumes, sediment supply and episodic storms, when wave action plays a very important part, brings about changes which make future prediction hazardous.

In the lower estuary by heavy mineral deposit study it is found that the net sediment movement is west to east direction. This is also supported by the wave action, which is strongly correlated with the wind directions (Fig. 4). Consequently, during the southwest monsoon waves strike the offshore region at an angle and cause a littoral drift in the eastward direction.

The bed profile at the mouth of the estuary shows that all the humps have a flatter slope towards east of the crest and a steeper slope towards the west. This obviously indicates considerable amount of sediment transport from east to west (Schields, 1936). This is explained by the fact that most of the storms blow into the estuary from a direction between south-south-east and east-south-east. However, this movement is otherwise during normal monsoon and the net movement is in the eastward direction as may be seen from the differential map (Fig.—5) for two survey, one carried during 1950 and the other in 1964.

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[4] Hydraulic Study Dept., Sp. Note No. 40

Considering the velocity predominance

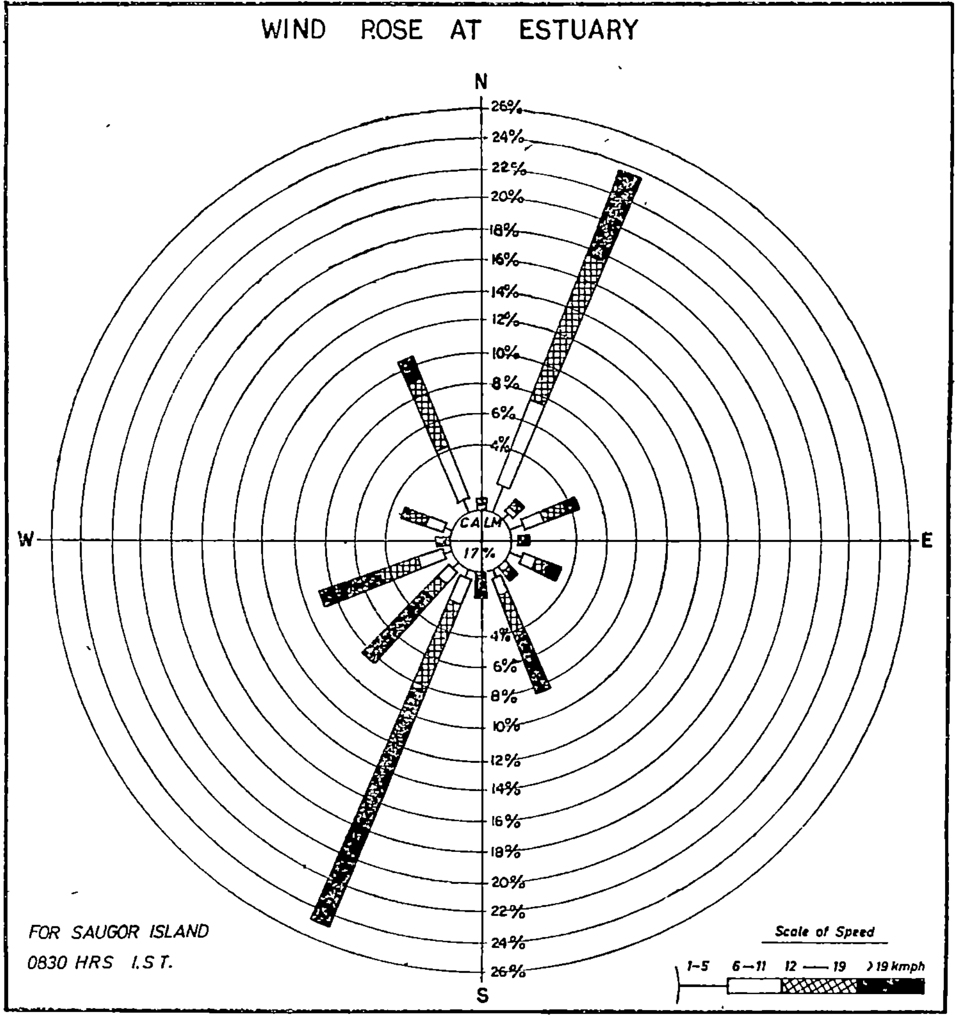

Fig. 4

at the bed of the estuary (Fig.—6) it is seen that the western side of the estuary has a flood predominance indicating a net upstream movement of sediment whereas the Eastern side has ebb predominance. It is likely that the material which enters along the west is pushed back through Auckland channel and Saugor Roads.

ACKNOWLEDGEMENT

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They are also grateful to Dr. S. K. Bhattacharya, Chief Hydraulic Engineer, Hydraulic Study Department, Calcutta Port Commissioners for critically reviewing the manuscript.

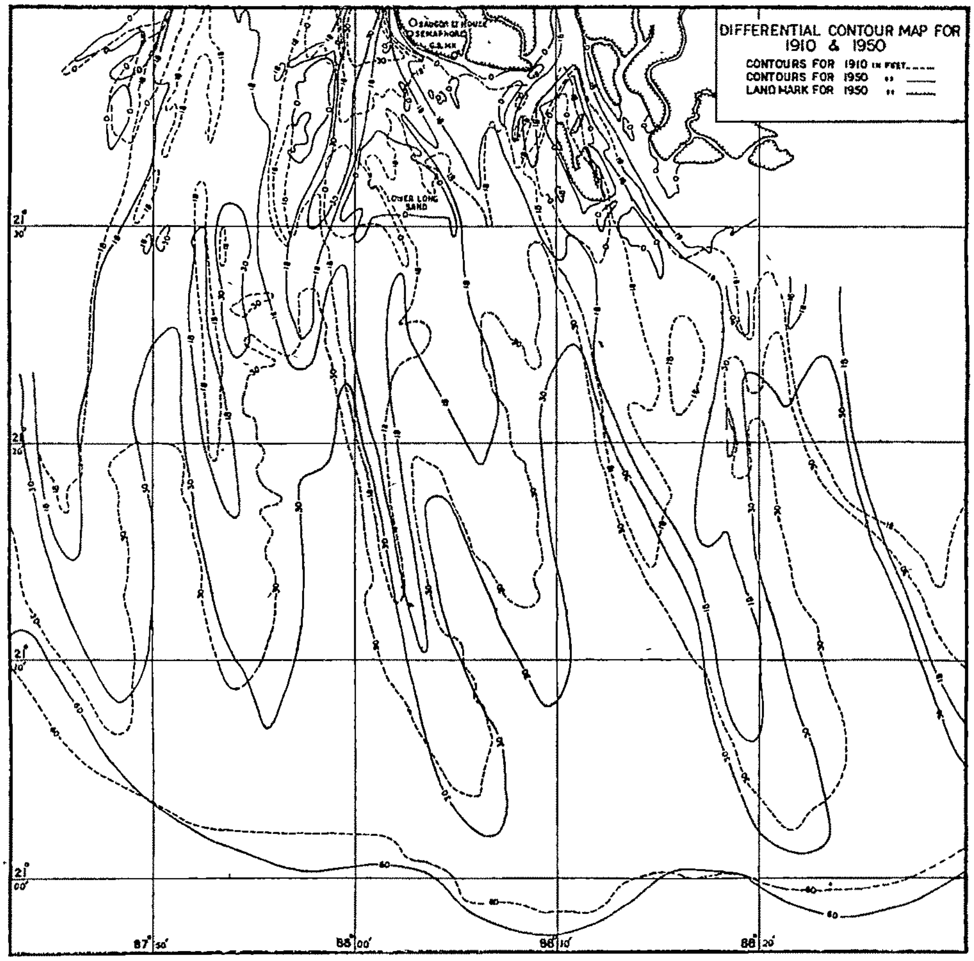

Fig. 5

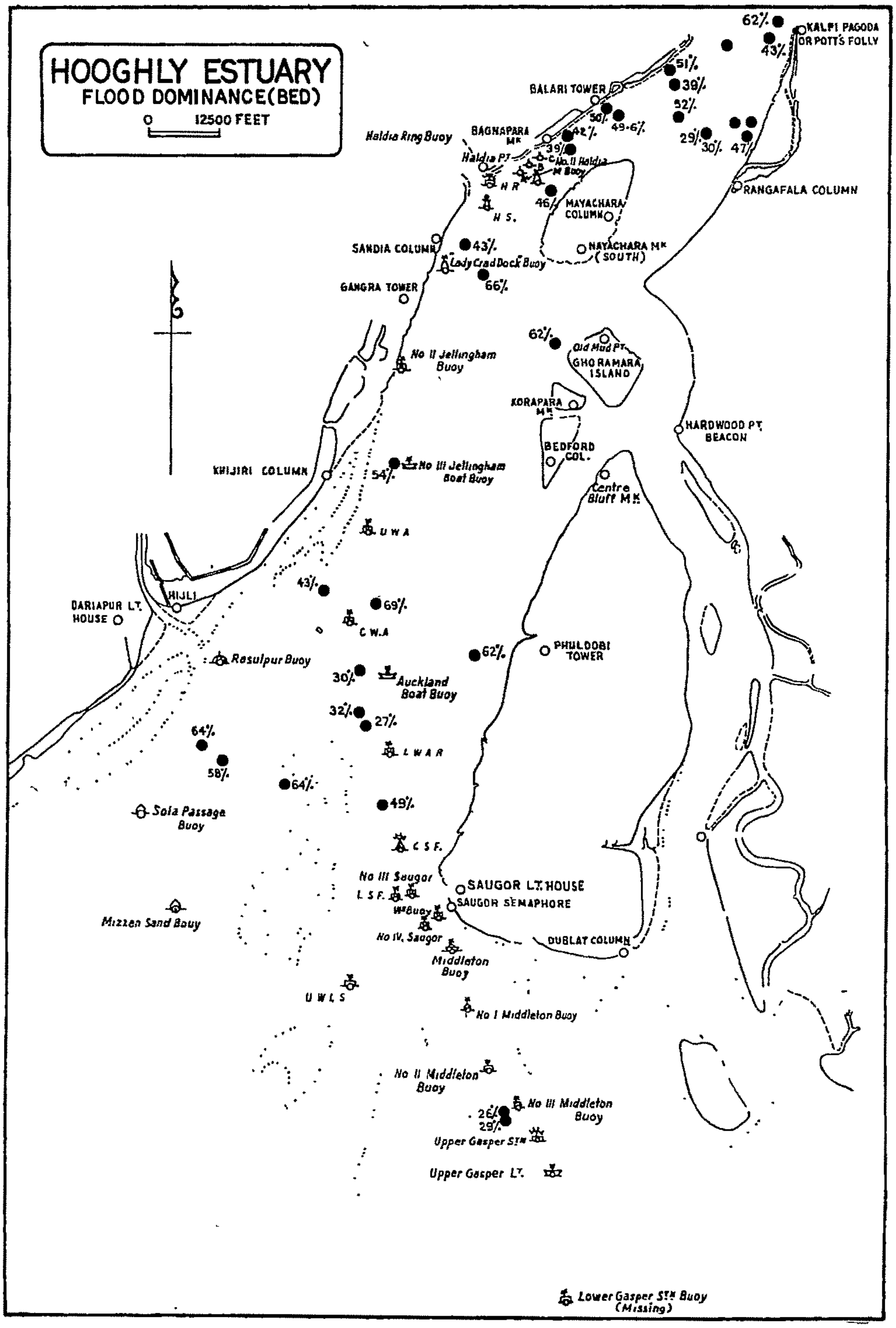
HOOGHLY ESTUARY
FLOOD DOMINANCE(BED)
0 12500 FEET
62%
KALPI PAGODA OR POTT'S FOLLY
43%
51%
39%
52%
BALARI TOWER
50%
49.6%
29%
30%
47%
Haldia Ring Buoy
BAGNAPARA MK
42%
39%
Haldia PT
C
B
No. II Haldia M Buoy
H R
H S.
46%
MAYACHARA COLUMN
RANGAFALA COLUMN
SANDIA COLUMN
43%
NAYACHARA MK (SOUTH)
Lady Crad Dock Buoy
66%
GANGRA TOWER
62%
Old Mud PT
GHO RAMARA ISLAND
No II Jellingham Buoy
KORAPARA MK
HARDWOOD PT BEACON
BEDFORD COL.
KHIJIRI COLUMN
54%
No III Jellingham Boat Buoy
Centre Bluff MK
U W A
43%
69%
HIJLI
DARIAPUR LT. HOUSE
C W.A
Rasulpur Buoy
62%
PHULDOBI TOWER
30%
Auckland Boat Buoy
32%
27%
64%
58%
L W A R
64%
49%
Sola Passage Buoy
C S F.
No III Saugor
L S F.
SAUGOR LT. HOUSE
SAUGOR SEMAPHORE
Wt Buoy
Mizzen Sand Bouy
No IV, Saugor
DUBLAT COLUMN
Middleton Buoy
U W L S
No I Middleton Buoy
No II Middleton Buoy
No III Middleton Buoy
26%
29%
Upper Gasper STN
Upper Gasper LT.
Lower Gasper STN Buoy (Missing)

Fig. 6

REFERENCES

Einstein, H. A. (1950) : *"The bed load function of sediment transportation in open channel flows"*, Tech. Bul No. 1026, Sept., U S. Dept. of Agr. Soil Conservation Service.

Hydraulic Study Dept (1969) : *"The regime of the Bhagirathi-Hooghly System"*, Sp. Note No. 40, July, Calcutta Port Commissiners.

— (1969) : *"System Analysis on High Speed Digital Computer for the Upper Hooghly Channel"*, Sp. Note No. 43, July, Calcutta Port Commissioners.

— (1969) : *"A note on the quantum of the upland discharge required for the Hooghly during the dry season"*, Sp. Note No. 45, July, Calcutta Port Commissioners.

— (1969) : *"Tides and the Tidal Propagation in the Hooghly"*, Sp. Note No. 47, July, Calcutta Port Commissioners

Kalinske, A. A. (1947) : *"Movement of sediment as bed load in rivers"*, Trans. Am. Geophy. Union, Vol. 28, No. 4, Aug.

Roy, S. C. (1969) : *"Hydraulic Investigations on behalf of Hooghly Estuary"*. Mitteilungen des Franzius Instituts fur Grund-und Wasserbau der Technischen Universitat Hannover, Heft 32, Hannover.

Schields, A. (1936) : *Anwendung der Ahnlichkeits—Mechanik und der Turbulenz-forschung auf die Geschiebe wegung*, Preussische Versuch-sanstalt fur Wassenbau und Schiffbau, Berlin.

SOILS OF THE SUNDARBANS

S. BHATTACHARYYA

Abstract

The alluvial plains of Sundarbans consist of complex patterns of tidal rivers and creeks, mud flats and newly formed islands. Some of these islands are swampy morasses covered with mangrove vegetation. A greater part of the region has been reclaimed for cultivation and settlement. Only about 300 sq. miles still remain under dense tropical jungles. This paper deals with the properties of coastal saline soils of the region and their effects on vegetation. An attempt has also been made on a classification of the soils based on U.S.D.A. classification schemes for saline soils.

The Sundarbun area is demarcated from the rest of the district of 24-Parganas by a slightly zig-zag line drawn from a point a few miles north of the Sagar Island and running north-east ward to a point on the Ichhamati near Basirhat. On the east, the Sundarbans are bounded by the rivers Ichhamati, Kalindi and Raimangal, on the west by the Hooghly and on the south by the Bay of Bengal. It comprises an area of about 3100 sq. miles of which 1,630 sq. miles are controlled by the Forest Division of the 24-Parganas. Actual forest-covered land, at present, is little over 300 sq. miles. A large part of the Sundarbans has been reclaimed for cultivation and settlement.

Structurally, the Sundarban area comprises the southern part of the Ganga Delta, and is formed by alluvial deposits of the Ganga System. Data obtained from a number of fairly deep boarings in the adjacent areas of Calcutta show that the deltaic alluvium consists of alternations of clay, sand and silt together with a few bands of gravel. The depth of the alluvium is considerable. A boaring near Akra Road in the Garden Reach Municipality reached a depth of 1,306 feet without sign of a rocky bottom.

Topographically, the Sundarban of West Bengal is an absolutely flat land with elevations little above the high tide level. Only along the river courses natural levees rise above the flood plain. The Sundarbans are traversed by numerous tidal rivers and estuaries of which the Hooghly, the Saptamukhi, the Takhuran, the Matla and Raimangal are important. These rivers do not flow in a single channel but in a multitude of anastomosing channels which generally spill over the adjoining lands and deposit enormous amount of sediments in the flood plain.

Though a large part of the Sundarbans has been reclaimed for cultivation and settlement, the south and eastern parts still await development, within this region there are many small islands which are so densely clothed with mangrove swamps that human penetration is almost impossible. Of these islands Sagar Island between the Hooghly and channel creek is the largest and most important, and itself cut into many smaller islands by cross streams. Besides, Fraserganj, west of Saptamukhi, Lothian and Henry Island in the mouth of Saptamukhi, Bulcherry between Jamira and Matla, Holiday Island in the Matla and Gosaba, Bangadhuni at the mouth of Gosaba and few others under Baruipur protected forests are significant.

CLIMATE

The climate of the Sundarban areas is of tropical monsoon type with distinct dry season in the low sun period. January is the coldest month when temperature rarely falls below 10°C, and the ameliorating effect of the warm sea makes the climate quite pleasant. Summers are hot and oppressive with average temperature reaching above 29°C, and absolute maxima may approach 38° or 40°C.

Rainfall begins in the month of April and continues till October. The region is ravaged by Nor'wester storms in the month of April and May and sometimes in March These sudden and violent storms usually develop in the afternoon and is accompanied by thunder, lightning and torrential rain for a short duration. In the middle of June the monsoon sets in with abundant and widespread rainfall which may exceed 200 mm. in many stations. It has been found that the intensity of rainfall is greater in the month of October than any other months. The increased intensity of precipitation over an already saturated soil area results in water logging in the lowlying tracts for a considerable length of time.

NATURAL VEGETATION

The Sundarban forests consist of trees of evergreen species of shrubs and palms. Along the coast there are tidal mangrove swamps of low height. The trees are peculiar to the tidal swamps and can thrive well in coastal saline soil. They are characterised by their peculiar root developments which can be seen above the soil when the tide water recedes. Among the big trees the 'Sundri' (*Heritiera minor*) is very common. It grows best on the drier lands near the streams where the salinity is moderate. 'Golpata' prefers low salinity and grows best on ever moist mud-banks. Other plants which are found to flourish in the saline soils are 'gengwa' (*Excecaria agollocha*), 'hital' (*Phonix palmdosa*), 'baen' (*Avicenuia officinalis*), 'bhora' (*Rhizophora mueronata*) and Kaora (*Soumeratia apatata*). Besides, there are various types of bushy plants and creepers which can tolerate a considerable degree of salinity.

SOILS

The deltaic soils of the Sundarban region are very productive for their favourable physical and chemical properties. Soils when occur in any considerable extent and are subjected to flood control and drainage become very important for agriculture.

The Sundarban soils are light gray, pale-olive or olive gray in colour. The parent material is the Ganga alluvium. A number of profiles have been examined in different places of the Sundarbans at grid-intervals of 8 miles. The morphology of the soil profile indicates that the profiles are of very recent origin. The soils have not yet received enough time to reach maturity so that soil horizons are imperfectly developed. There are no signs of water logging within the profile but soils are generally moist.

Organic matter in the soil is low. It varies usually between 0.75% and 2.0% and in a few cases, it exceeds 2.0%. An enrichment zone at a depth of 24 to 30 inches from the surface are seen in soils collected from Kakdwip, Namkhana, Henry Island, Lothian Island and at Gobardhanpur South. This enrichment layer of organic matter may be due to percolation of water containing organic substances through upper layer to this zone, after which soil is more clayey than upper layers.

The textural nature of the soil was ascertained from the data obtained from the analysis of a large number of soil samples from different localities. Soils contain mainly clay, silt and fine sand. The amount of coarse sand is very insignificant, the percentage being less than 1, and in some soil samples, it is even less than 0 5. Texturally, soils of this area are either silt loams or clay-loams. It has been found that proportion of clay increases with depth.

The Sundarban soils can be classified into four main types, (1) Saline soil, (2) Saline-alkali soil, (3) Non saline alkali soils and (4) degraded alkali soil. (Fig.—1).

Saline soils are found in the flood-plains of rivers and in natural depressions along the sides of rivers and creeks. The rivers discharge enormous volume of water along with silt and clay in suspension to the sea ; particles of clay and silt undergo partial transformation in their exchange complex due to exchange re-action with sodium chloride of sea water. These salinised particles of silt and clay are brought back by tides and deposited over the lowlying areas and depressions behind the levees with the formation of saline soils.

In wide areas of the P.S. of Falta, Jaynagore, Mathurapur, Canning, Sandeshkhali and Hasnabad have such soil deposits.

Whenever, the tide water containing sufficient sodium salt floods a fresh lowland soil area with excess of alkali it makes the soil enriched with Na- ions in the similar process that happens when the silt and clay-loads are pushed into the sea water by rivers. The resultant soil that is formed is the saline-alkaline soil. Saline-alkaline soils are found to occur widely in the Islands of Sagar, Kakdwip, Namkhana, Mansini, Frazerganj, Rakashkhali and throughout the southern deltaic part of West Bengal in general. Limited areas of occurrences of saline-alkaline soil can be found in the Police Station of Kulpi, Mathurapur, Canning and Sandeshkhali.

Rain water brings about changes in the

nature of deposit as a result of leaching under different environmental conditions. For instance, salts when partially leached away in absence of dolomite in the original deposit and Na-ions entering the exchange complex in presence of excess of salts saline- alkali soil results.

Where salts are completely removed

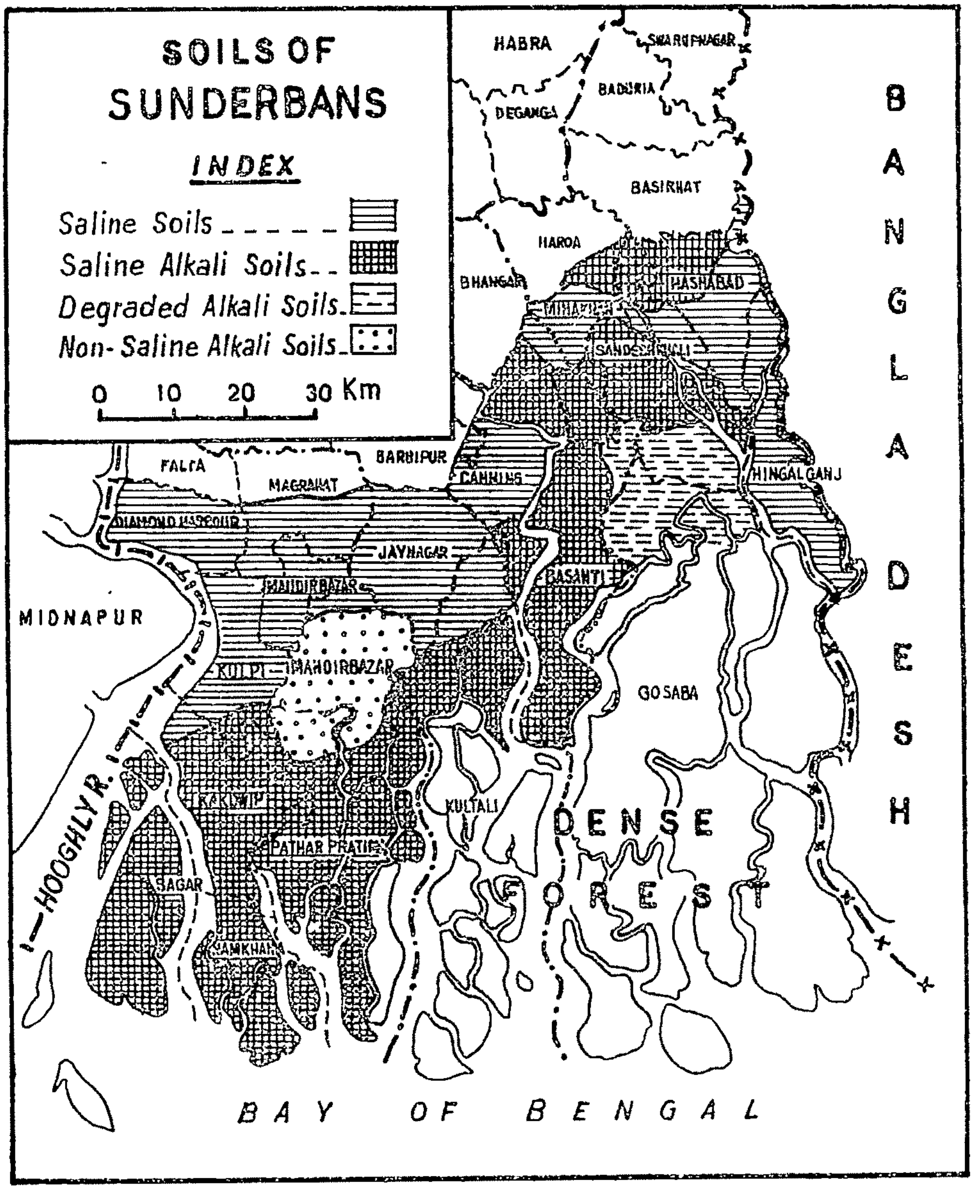

Fig. 1

(In this figure in the Non-Saline Alkali Soils the name of the P.S. is to be read as "MATHURAPUR") through leaching with rain water non-saline alkali soils are formed. Such a soil is seen to occur in patches in the P S. of Mathurapur. The thickness of the zone is about 4-5 miles, south of this zone and upto the Bay, soil is mostly saline-alkali containing 0.2 to 1.2% salt. pH of the non-saline-alkali soil of this locality usually varies from 8.2 to 8.6, and sometimes more.

Another type of soil known as degraded alkali soil (Sigmond, 1934) or saline Turf soil has been formed in regions where the process of leaching has taken place in presence of half decomposed organic matter lying within a zone of 4 to 6 feet of the surface. H-ion from organic acids liberated from the semi-decomposed organic residues also takes part in the formation of such soil. The organic acids and high salt content . have formed saline unsaturated soils. Degraded saline soil is widely found in the P.S. of Sandeshkhali and in the adjacent areas of Canning P.S. and in the southern part of Hasnabad P.S. Vegetation is strongly influenced by the amount of salt present in it. Large areas are flooded by saline water during the high tide, others are protected by embankments. Even on the protected lands incrustations of sodium salt can be found on the surface during the dry season (winter) when capillarity is at its maximum intensity, and on such soils vegetation growth is stunted. The high amount of sodium chloride and sulphate in soils has detrimental effects on growing plant . Such saline soil interferes with the absorption of water by plants through the development of higher osmotic value in the soil solution than that exists in the root cells. In addition, entrance of nutrient ions into root cells is influenced by the nature and concentration of other ions. Hilgard (1921) believes that absorption of water by roots begins to diminish as soon as concentration of saline solution approaches or extends one-half percent, while when it rises as high as 3% water absorption ceases even in the wetted soil and plants suffer from drought. Probably as a result of this plants on the virgin lands, occasionally inundated by brakish water, have dwarfish appearance. Also the low productivity of the soil of recently reclaimed virgin lands is for the presence of excessive amount of sodium salt.

REFERENCES

Bhattacharjee, S. (1968) : *Pedogenesis and Landuse in Western Sundarban,* 21st I.G.C. New Delhi.

Chatterjee, S. P. (1945) : *Land utilization in the District of 24 Parganas, Bengal,* Cal. Geo. Soc., Calcutta.

Govt. of W. Bengal, Directorate of Agriculture (1966) : *A Report on Soil Work in West Bengal* Vol. III District 24 Parganas.

Hilgard, E. W. (1921) : *Soils,* Macmillan Co. New York.

Sigmond, A. J. de (1938) : *Principles of Soil Science,* Thomas Murby & Co. London.

U. S. D. A. (1953) : *Diagnosis and Improvement of Saline and Alkali Soils.* Agriculture Handbook No. 60, Washington D.C.

PART TWO

MEANDER CHARACTERISTICS OF BHAGIRATHI IN RELATION TO ITS TRANSPORT CAPACITIES

A. N. BISWAS & K. K. BANDYOPADHYAY

Abstract

Bhagirathi Meanders are characterised as "primary" and "secondary". Primary meanders are associated with high transport capacities due to steep bed slopes on account of excessive deposition of charge. Secondary meanders transport near equilibrium charge at flat bed slopes. Meander parameters defined by bend radius and wave length appear to be related to the transport capacities. Perennial head water supply with controlled silt charge in the Bhagirathi will alter its transport capacities considerably. This study indicates the necessity of further investigations into possibility of meander formations in the post Farakka Barrage operation period.

Various approaches to meander formation indicates that although importance of charge has been appreciated, no definite correlation has been established between meander parameters, sediment charge, slope, discharges etc. (Bandyopadhyay and Biswas, 1970).

Meander formation in alluvial channels is usually characterised as "primary" and "secondary" meanders. "Primary" meanders occur in a channel when charge in excess of "equilibrium charge" is fed into it at the source. Equilibrium charge may be defined as the charge carried by the channel consistent with slope and discharge. In the primary meanders, the excess charge crosses over to the convex bank. "Secondary" meanders are generated by local bank erosion and consequent local overloading and deposition by the river of the heavier sediments moving along the bed. At the downstream section of the eroding zone, the bank side velocity drops due to straightening out of the channel Consequently, the transport capacity drops. The material gets deposited as a shoal along the same bank. In the classic model experiments of Friedkin (1945), basic cause of meandering was established to be due to local bank erosion and deposition. These meanders, however, can only be identified as "secondary" meanders (Inglis, 1949).

Modern hydrodynamical theories on meander formation (Einstein and Li, 1949, Einstein and Shen, 1964) emphasise the formation of meanders as a consequence of helicoidal currents. This treatment, however, does not explain the reasons for the initiation of primary and secondary meanders. Looking to the basic cause of meander formation, it is appreciated that sediment deposition and erosion in conjunction with other hydraulic parameters initiate meander formation All these parameters are aptly defined by the sediment transport capacity of a channel. Hence, it is felt that the different characteristics of the meanders should be primarily related to the transport capacities. An attempt has been made to study meander characteristics in relation to transport capacities of a channel. Formation of Bhagirathi meanders are explained in this light.

SEDIMENTS TRANSPORT CAPACITY OF A CHANNEL AND MECHANISM OF MEANDER FORMATION

Sources of the sediments drained into a river are charactrised by the catchment area, the bed and bank of the channel itself and organic material. All channels transport detritus to a greater or lesser extent depending on the characteristics of the water shed, the distribution of the annual rainfall and the hydraulics of the channel. Sources of these materials were land masses of previous geologic ages. It is evident that there is no apparent natural control over these sources. Sediment supply from these sources generally follow the transport law (Bogardi,1961) $C = KQ^n$

where C = sediment charge
Q = discharge
K, n = Constants

The law is general, and in reality the sediment charge varies considerably at the same discharge.

Similarly the transport capacity of an alluvial channel varies at the same discharge depending on the state of the channel. Einstein (1950) explains sediment transport capacity as the capacity of an alluvial channel to transport the different grain sizes of its alluvial bed at various flows consistent with the prevailing hydraulic parameters. If the sediment supplied is in excess of transport capacity deposition occurs and vice-versa. It is important to note that the sediment transport capacity includes only the bed material load and not the wash load which contributes about 80 per cent (Chow, 1964) of the suspended load from the sources mentioned earlier. It is this bed material load which settles largely on the bed in case of the channel transport capacity being lower than the load washed in. Also, a large concentration of fine material in suspension alters the transport capacities of a channel (Colby, 1964).

Thus, due to either variation in hydrograph or silt charge simultaneously or independently, and with a transport capacity less than the sediment charge fed, settlement occurs and primary meanders are generated. With rapid settlement at specific localities, secondary currents are accentuated and meanders are initiated. Thus, sediment transport capacity in relation to the charge fed in, is the guide line to the formation of meander pattern. Meander formation in Bhagirathi are examined in this context.

THE BHAGIRATHI AND ITS TRANSPORT CAPACITIES

The Bhagirathi draws an uncontrolled amount of sediment from the Ganga at

Biswanathpur. A close scrutiny of the 144 mile long river from Biswanathpur to Nabadwip shows (Map at the end):

(a) Presence of extensive shoals in the river reach from Biswanathpur to Berhampore, a distance of 48 miles. The reach consists of a number of meanders with high sinuosity (about 1.7),

(b) A comparatively stable reach of 48 miles between Berhampore and Katwa having local bank erosion,

(c) A stretch of 48 miles from Katwa to Nabadwip, comprising of heavy bank erosion and shoal areas. Meanders have both high and low sinuosity.

Transport capacities were computed at 28 sections with about 10 sections located in every section. It is important to note that the transport capacities would vary from section to section, due to sorting of bed materials, recurring scour and deposition, confluence of tributaries, unusual physical characteristics etc. In such a case, the transport capacities of the river would be the average of the transport capacities at a number of sections located over a long length, taking cognisance of all types of sections which are in the process of scour or deposition. A modification of Einstein's (1950) method and the Step method of computation recommended by U.S.B.R.[1] was used to compute the transport capacities at the sections.[2] The different reaches of the Bhagirathi are now examined in relation to transport capacities.

The river from Biswanathpur to Berhampore

The average transport capacities of the reach from computed capacities at individual sections for discharges of 20,000 cfs., 40,000 cfs., and 59,000 cfs. and measured suspended bed material load at Jangipur (about 8 miles downstream of Biswanathpur) are as follows:

Discharge cfs	Average transport capacity tons/day (computed)	Measured suspended load at Jangipur tons/day
20,000	3,581	6,616
40,000	16,891	24,439
59,000	35,127	39,313

Measured loads are about 100 per cent higher in the discharge range of 20,000 cfs—40,000 cfs, the capacity and the supplied charge balancing somewhat at higher discharge. The discharge range of 20,000 cfs—40,000 cfs persists in the Bhagirathi for a longer duration during the freshets. This is evidenced from cross sections of the river, which deteriorates at discharges below 40,000 cfs and improves at higher discharges. Also, the fact that the reach under consideration is composed of a large number of shoals, indicates that the channel receives excess sediment during greater part of the monsoon. Referring to the earlier definition of primary meanders, this reach of the river, therefore, exhibits primary meanders.

The river from Berhampore to Katwa

Computed average capacities register a fall compared to the upstream reach (see table in the next page).

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[1] Sediment Section of Projects Investigating Division, Burean of Reclamation 1955.

[2] Unpublished Report of the Hydraulic Study Dept., Nov. 1966.

Discharge cfs.	Average computed transport capacity tons/day
20,000	2,780
40,000	15,000

Significant shoaling characteristics are absent in this length of the river. The excessive load has already deposited in the earlier length. Consequently, the main source of sediment supply is from bed and bank erosion. The river is characterised by low sinuosity, i e. higher wave length of meanders, and deposition on the bed on the same side of bank erosion. The meanders conform to "secondary" meanders.

Primary meander characteristic are only discernible in this length, near the outfull of river Babla, into the Bhagirathi. This is perhaps due to excessive load being injected by the outfalling tributary. Characteristically, the transport capacities also show a rise here. The capacities are 7,904 tons/day, and 52,359 tons/day for 20,000 cfs and 40,000 cfs respectively.

River from Katwa to Nabadwip

The Ajay falls into the Bhagirathi at Katwa. This stretch exhibits both primary and secondary characteristics. Ajay is a flashy tributary and brings down predominantly coarse load Downstream of the outfall, the Bhagirathi meanders for a distance of about 26 miles. Transport capacity is high over this length. In the following length, the river again shows secondary characteristics with low transport capacities, the excess load from Ajay having deposited in the earlier stretch. The terminal length of about 10 miles is influenced by the backwater effect of Jalangi. Table 1 below shows the computed average transport capacities.

TABLE 1

Item	Discharge cfs	Average Transport capacities (computed) tons/day
26 miles long stretch below outfall of Ajay	20,000	5,7 1
	40,000	29,990
Following length	20,000	2,412
	40,000	7,312

DISCUSSIONS AND CONCLUSIONS

Table 2 shows the physical characteristics of some meanders—primary and secondary—selected in the reaches discussed earlier and their capacities. The data shows higher transport capacities consistent with formation of primary meanders. This is due to slopes becoming steeper in the reaches, subsequent to deposition of excessive charge. Bend radii are sharp and wave lengths are small due to accentuation of secondary currents as a result of deposition on the bed. Further, secondary meanders are characterised by low transport capacities and flat slopes. Bend radii are not sharp and wave lengths are comparatively large. Since the secondary meanders transport near-equilibrium charge they are comparatively narrow and deep than the primary meanders which are wide and shallow, assuming of course that the banks are erodible. Model experiments also conform to this finding (Lipscomb, 1953). It is important to note in this connection that with the introduction of perennial upland supply into the Bhagirathi-Hooghly complex from the Farakka

Barrage, the transport capacities will alter considerably with changes in slope, consequent upon partial control of charge fed into the river system. Change in meander characteristics as a result would be an appropriate subject for further studies.

ACKNOWLEDGEMENT

The authors are grateful to Dr. S. K. Bhattacharya, Chief Hydraulic Engineer, Calcutta Port Commissioners, for his encouragement in these studies.

TABLE 2

Reach of the river	Meander location downstream of Biswanathpur off-take in miles	Radius of Meander in ft.	Amplitude of meander in ft.	Meander length in ft.	Meander Wave Length in ft.	Computed Average Transport capacities (Tons/Day) of the reach in col. 1 for		Remarks
						20,000 cfs.	40,000 cfs.	
1	2	3	4	5	6	7		8
Biswanathpur to Berhampore	19	1980	7960	21750	12375	3581	16891	Primary Meander
Berhampore to Katwa	44 67	3630 3165	3960 6200	26400 23925	17259 18876	2780	15000	Secondary Meander
	90	2115	3830	15923	12804	7904	52359	Primary Meander below Babla Outfall
Katwa to Nabadwip	132	3415	6830	21120	13827	2412	7320	Secondary Meander

REFERENCES

Bandyopadhyay and Biswas (1970) : *Meander Characteristics of Bhagirathi*—Paper accepted at the 40th Research Session of the Central Board of Irrigation & Power, Shillong.

Bogardi, J. (1961) : *Some Aspects of the application of the theory of sediment transportation to Engineering problems*—Jour. of Geophysical Research, Vol. 66, No. 10.

Chow Ven Te (1964) : *Handbook of Applied Hydrology*, McGraw Hill Book Co., pp. 17-55.

Colby, B. R. (1964) : *Practical computations of bed material discharge*,—Jour. of the Hyd. Div., ASCE, Vol. 90, No. HY 2, March, Part I.

Einstein, H. A. (1950) : *The bed load function for sediment Transportation in open channel flows*—Tech. Bulletin No. 1026, U.S. Dept. of Agriculture.

— and Li (1958) : *Secondary currents in straight channels*, Trans. Am. Geophysical Union, Vol. 39, No. 6.

— and Shen, H. W. (1964) : *A Study of Meandering in straight alluvial channels*—Jour. of Geophysical Research, Vol. 69, No. 34, December.

Friedkin, J. F. (1945) : *A Laboratory study of the Meandering of Alluvial Rivers*—U.S. Waterways Expt. Station, Vicksburg, Mississippi.

Hydraulic Study Dept. (1966) : *The Bhagirathi Studies—The Report on the Improvement of the Bhagirathi*—Unpublished report, Calcutta Port Commissioners, (Nov.).

Inglis, C. (1949) : *The behaviour and control of Rivers and Canals (with the aid of models)*—Part I, CWIRS Research Publication No. 13, pp. 151.

Lipscomb, E. B. (1953) : *The techniques and application of hydraulic studies involving movable beds*—Proc of the Fifth Hydraulic Conference, June 9-11, 1952, Iowa Institute of Hydraulic Research, University of Iowa City, Iowa.

U.S.B.R. (1965) : *Step Method for computing total sediment load by the modified Einstein Procedure*—Sediment Section of Projects Investigation Division, Bureau of Reclamation, (July).

A LABORATORY STUDY ON MEANDERING OF STREAMS WITH ANALYSIS OF SOME MEANDERS OF BHAGIRATHI RIVER

P. B. Ray & A. K. Datta

Abstract

The paper begins with a brief investigation into the question why meanders form at all in streams and rivers. Then, particulars of the set up of the laboratory study on meandering by the River Research Institute, West Bengal, and the more important results are given. The existence of a critical slope for meander formation, the association of steeper slopes with braiding, formation of alternate deep concave bends and high convex bars in model streams, effect of sand injection, importance of energised flow on meandering and some correlations of meander length, meander breadth, discharge, sand charge, and their ratios are features of the paper.

Also from the study of statistical correlations of the lengths and breadths of some of the meanders of Bhagirathi river, the existence in that river of two different types of meanders, the tortuosity, of one being more than that of the other, was hinted at.

Our knowledge about the process of development of meanders in channels with erodible bed and bank is not sufficient for taking necessary measures for flood control and other protection works. As such it is worthwhile to conduct fundamental research to have a clear understanding regarding the formation of meanders and the relationship between different factors affecting meandering. In performing such studies the first point that arises is why rivers and channels meander. One school of thought says that meandering occurs when there is excess slope, the river lengthening its course to reduce the slope. Another school says that the primary cause of meandering in incoherent alluvium is insufficient slope i.e. insufficient energy to keep the charge in motion resulting in throwing down a part of the charge on one bank and thereby developing curvature of flow. Both the schools seem to have considered discharge, silt charge and slope as the only factors governing the process of meanders, whilst Sternberg (1875), Schoklitsch[1] and other consider that diameter of sand must also be another important factor in the process of meandering.

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[1] Der Wasserban, Vol. 1, p. 143.

There are, however, reasons to suppose that the truth lies midway between the two completely divergent views of the contending schools of thought mentioned above. That is to say, the real cause of meandering is neither the excess of slope nor the smallness of it. It is rather the difference of slope on the upper and lower reaches of any natural channel that is responsible for causing meandering in the lower reaches. In the upper reaches where the slope is comparatively steep, the velocity is high and coarser materials are picked up in a large quantity by the flowing water. In the lower reaches where the slope is flatter, the velocity is low and the flowing water can no longer hold the entire charge, and deposition starts. It is from this deposition of the induced charge that meandering starts.

Friedkin (1945) is of opinion that meandering results primarily from local bank erosion and consequent local overloading and deposition by the river of heavier sediments which move along the bed. According to this, meandering is essentially a natural trading process of sediments from banks to bars. Sand entering at the head of an alluvial river travels only a short distance before it deposits on bars along the inside of bends and is replaced by sand eroding from concave banks. In turn the sand from the caving bank of a bend travel only a short distance before it deposits on bars and is replaced by sand from caving bank. The rate of trading depends upon the rate of bank caving. Every phase of meandering represents a changing relationship between the flow and hydraulic properties of the channel, the amount of sand moving along the bed, and the rate of bank erosion.

In this respect considerable work was done at the Poona Research Station[2] some years back. These studies have clearly shown that rivers begin to meander as soon as they are unable to carry bed and suspended load with the discharge available. Such meanders are the *primary meanders*. *Secondary meanders* develop in the old, dying (moribund) rivers. In such rivers the charge is in deficit in the initial stages, and hence the rivers pick up load on the way causing bank erosion and bed scour. When the charge becomes excessive it leads to secondary meanders. Experiments have also shown that meander length varies as the square root of the discharge. These results confirmed the meander analysis of a large number of rivers in India and abroad.

From what has been said above it may be clear that the primary factors causing meanders are discharge, silt charge and slope. Grain size is also an important factor for development of meanders (Dutta, 1961). When the silt charge is higher than the carrying capacity of the streams, the excess charge deposits and meandering takes place even with flatter slope. But our knowledge about the exact relationships are not yet perfect. Much more work, however, remains to be done in the laboratories to find out why braiding of channels occur. With these ends in view laboratory experiments have been conducted to study the process of development of meanders in channels with erodible bed and bank. In this connection a study on the prototype meanders in the Bhagirathi river was also conducted in order to find out, if possible, any correlation between the meander lengths and breadths.

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[2] Annual Reports (Technical), 1942-43.

LABORATORY STUDIES

The laboratory experiments were conducted in two sand trays, one 300 ft. (91.4 m) long and 16 ft. (4.9 m) wide and the other 340 ft. (103 6 m) long and 30 ft. (9.1 m) wide. The first one was open while the second tray is provided within a shed. The average diameter of sand in the trays is 0.43 mm and its uniformity modulus is 0.33. Series of experiments on meandering, braiding and avulsion of streams have so far been conducted with discharges varying from 0.10 cusec (0.0028 cumec) to 0 70 cusec (0.0198 cumec) in initially straight channels with trapezoidal sections having widths varying from 13 inches to 4.5 ft., depths varying from 1.5 inches to 4 inches and slopes 1 in 600, 1 in 400, 1 in 300, 1 in 278, 1 in 250, 1 in 238, 1 in 200 and 1 in 150. The sand charges were from 2 kg/hr to 7 kg/hr. The sand used for injection was also of 0.433 mm. average diameter. Only in one case, finer sand of average diameter 0.128 mm was used for injection. Hours of run were from 25 to 350. The initial channel was always straight, without any bend at the entrance.

The more important features of the experiments are :

(1) For any particular type of sand, there was a critical slope for meander formation. With a flatter slope there was no meandering even in very long hours of run. With a steeper slope, the meanders first formed and eventually broke up, and the result was a mixture of meandering and braiding. With a still steeper slope, the breaking up of the meander was to a far greater degree, and the final picture was one of complete braiding of smaller interwoven streams.

With the sand of 0.433 mm average diameter, the critical slope for meander formation was found to be 1 in 300. With 1 in 600 slope, and with 1 in 400 slope there was no meandering even in 350 hours of run. With 1 in 200 slope, there was complete braiding. (Figs. 1 & 2).

(2) When the slope was suitable for the size of the sand, meanders formed with deeper concave bends, with opposite high convex bars, and shallow crossings between any two bends.

(3) Meanders could be produced even without sand injection, but without sand injection the upstream part of the channel became deeper and wider ; and with sand injection the cross section and slope in the upstream part could be maintained. Further, with sand injection, the meanders were bigger in size, both in length and breadth.

(4) When meanders formed in model streams, meander length (x) and meander breadth (y) could be connected by the relation.

$y=0.27x+0.90$, with 90% correlation.

(5) Meander lengths as obtained in our experiments, varied from 18 ft. to 46 ft. and meander breadth from 5 ft. to 11 ft. and C_L of the empirical formula $M_L = C_L \sqrt{Q}$ varied from 36 to 78.7 and

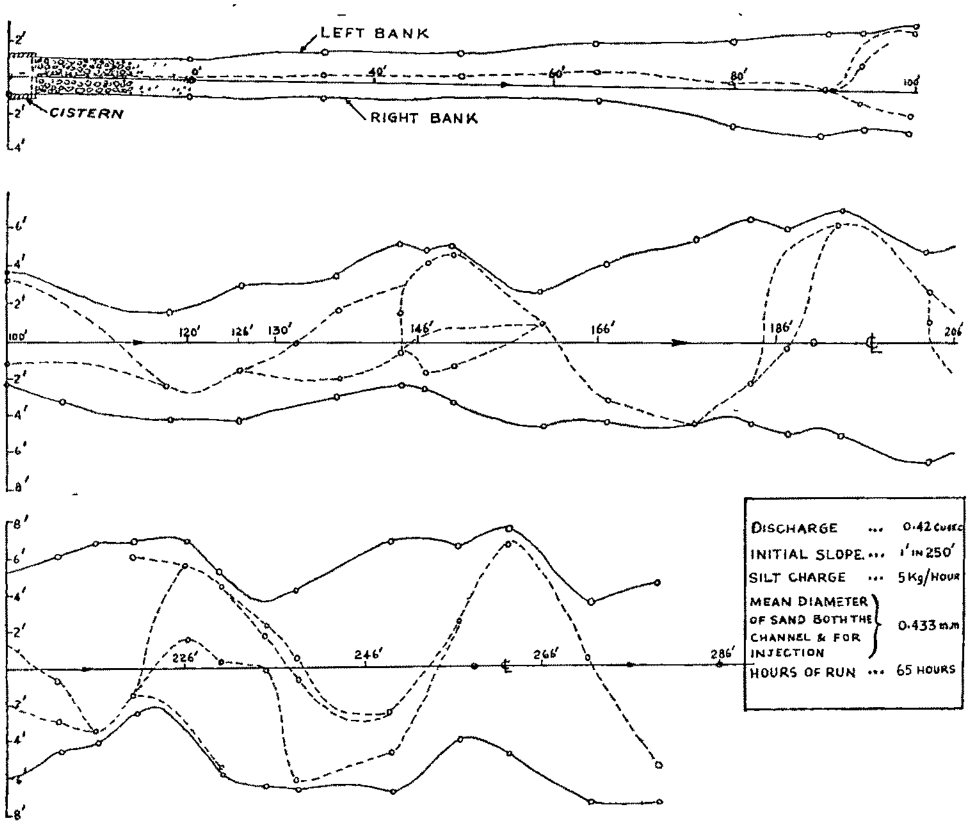
C_B of the empirical formula $M_B = C_B\sqrt{Q}$ varied from 10 to 17.7.[3]

Most of the values of C_L were comparable to prototype values, but the values of C_B in models were far less than prototype values, which were as high as 84.7 or 104.[4]

(6) In one case, with 1 in 300 slope, the average rate of downward travel of meanders was 8 ft/hr. in the model.

(7) With insufficient slope, i.e. less than the critical slope, no advantage was obtained in respect of meander formation by changing the depth or width of the channel.

(8) Though with a rather flat slope (1 in 600) there was no meandering even after 350 hours of run, if differential slopes were used, the slope in the upper half of the experimental channel being 1 in 200, and that in the lower half being 1 in 600, there were, however, good



Meandering of Streams

Fig. 1

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[3] C_L = Length coefficient ; C_B = Breadth coefficient.

[4] Annual Report (Technical) Poona, 19 2-4 .

meanders even in the flat lower half (1 in 600). The meanders in this case were gradually decreased in size, as the water energised in the upper steeper half part quickly dissipated its energy as it entered the lower flatter part. Further, it was found that if the lower part was very flat (Fig. 3) 1 in 800—there could form no regular meanders in it, even if the upper part were steeper (1 in 150).

(9) In an attempt to find some relation between M_L / M_B and Q_S / Q

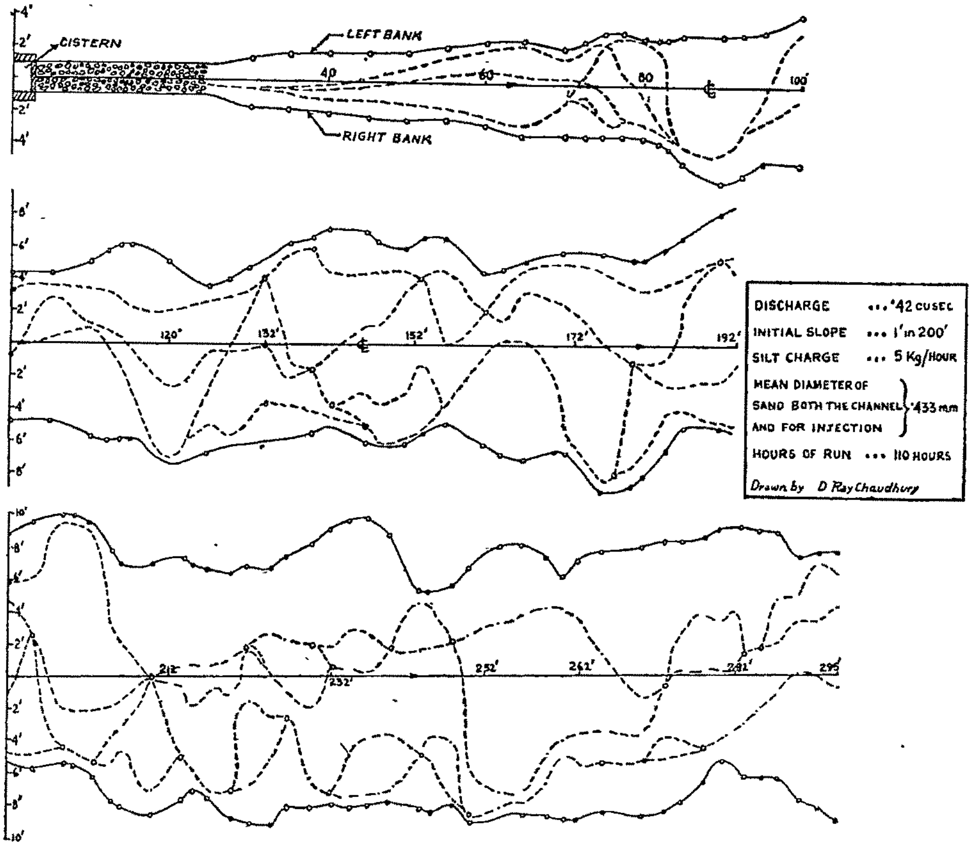
where M_L = meander length in ft,

M_B = meander breadth in ft,

Q_S = silt charge in cft/sec,

and Q = discharge in cft/sec.

the more consistent results were considered, and these are shown in Table 1. From a log-log plot of M_L / M_B against Q_S / Q (shown in Fig. 4) a relation of the form (Fig. 4) could be found by River Research Institute, West Bengal.

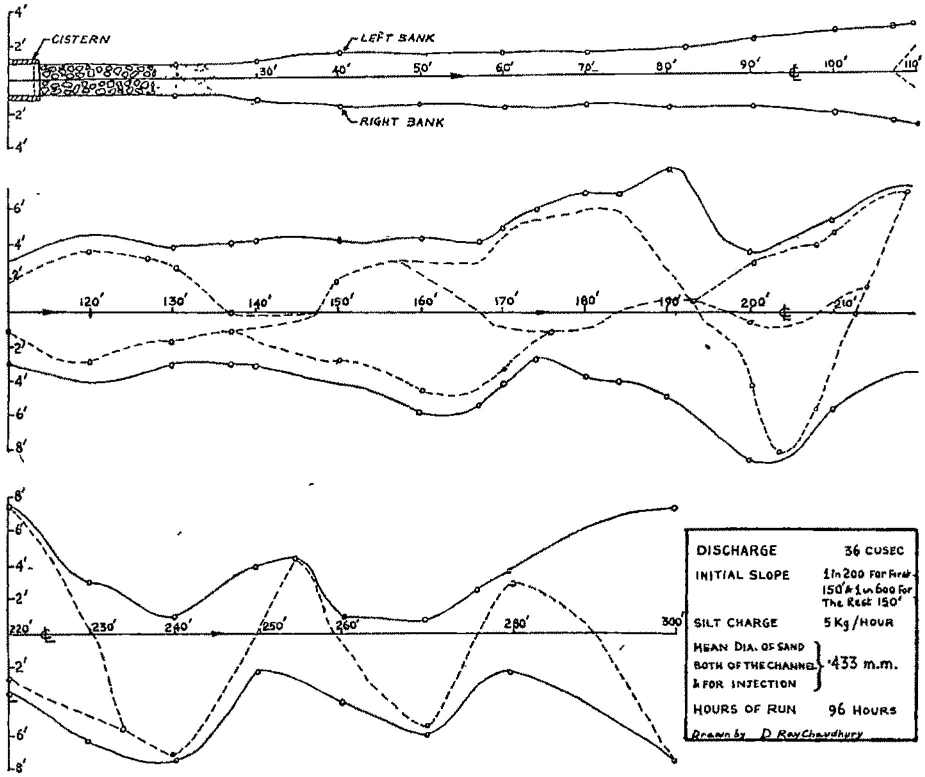

CISTERN
LEFT BANK
RIGHT BANK
40
60
80
100'
120'
132'
152'
172'
192'
212'
232'
252'
261'
281'
295'
4'
2'
6'
8'
10'
DISCHARGE ... ·42 CUSEC
INITIAL SLOPE ... 1' in 200'
SILT CHARGE ... 5 Kg/HOUR
MEAN DIAMETER OF SAND BOTH THE CHANNEL AND FOR INJECTION ·433 mm
HOURS OF RUN ... 110 HOURS
Drawn by D Ray Chaudhury

Meandering of Streams
Fig. 2

PROTOTYPE STUDY

The Bhagirathi is a profusely meandering stream and it was decided to study the meandering characteristics of this river. The maps of the Bhagirathi prepared in 1960-61 was taken as the basis of this study.

From survey maps several meanders of the river were identified, and their lengths and breadths were measured. From these data, an attempt was made to classify the meanders, and correlate their lengths and breadths. These meander data were taken from cross section 11 (Biswanathpur) to cross section 319 (Swarupganj) a stretch of about 150 miles (241.5 kms). Meanders were not however found throughout the whole length ; seventeen well formed meanders were obtained and their lengths and breadths were measured. The length and breadth and position of the meanders are shown in Table 2. The meander length and meander breadth, generally expressed as M_L and M_B have been denoted in this study by x and y respectively.



Meandering of Streams

Fig. 3

The minimum value of M_L / M_B was 1.25 and the maximum value was 2.83, amongst all the 17 meanders. Assuming a linear relation to exist between meander length (x) and meander breadth (y) of the form

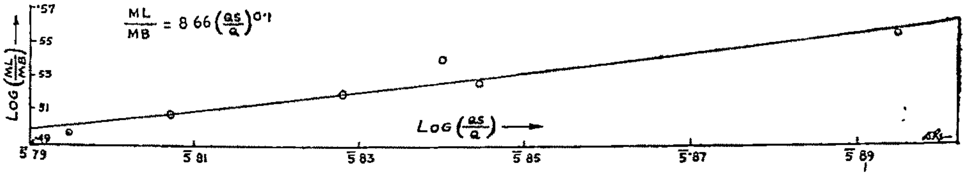
$$y=ax+b \quad \dots (1)$$

and applying Gauss' method of least square of errors the straight line fit becomes,

$$y=0.309x+4212 \quad \dots (2)$$

and the correlation coefficient for all the 17 meanders considered together is found to be 43%. As this value of the correlation coefficient is rather low, the linear fit for all the 17 meanders considered together, as indicated by (2) is not a good one.

The idea of considering all the 17 meanders together was, therefore, abandoned. The meanders were separated into two groups—one group consisting of 10 meanders, the ratio M_L / M_B of which varied from a maximum of 1.84 to a minimum of 1.25 (particulars of these 10 meanders are given in Table—3) and another group consisting of 7 other meanders, the ratio M_L / M_B of which varied from a maximum of 2.83 to a minimum of 2.01. The smaller values naturally indicated more tortuosity and greater values indicated less tortuosity of the river Bhagirathi. The particulars of the group of 7 meanders are given in Table-4.



Meandering of Streams

Fig. 4

From Table-3 it is seen that the straight line fit for the group of 10 meanders becomes—

$$y = 0.595\,X + 1014 \quad \ldots\ldots\ldots\ldots (3)$$

and the correlation coefficient for these 10 meanders is 80%.

Again, from Table-4 it may be seen that the straight line fit for the group of 7 meander becomes—

$$y = 0.422\,X + 60 \quad \ldots\ldots\ldots (4)$$

and the correlation coefficient for these 7 meanders is 84%. Thus:

For all the 17 meanders, correlation coefficient=43% ; for the group of 10 meanders, correlation coefficient=80% and for the group, of 7 meanders, correlation coefficient=84%.

From above values of the correlation coefficient, it may be concluded that :

(i) All the meanders of river Bhagirathi are not of the same character, as the correlation coefficient of 43% for all together is low.

(ii) The meanders of the groups of 10 shown in Table-3 are of similar character amongst themselves, as the correlation coefficient of 80% is fairly high.

(iii) The meanders of the group of 7 shown in Table-4 are of another character, (as the lines of fit of the two groups, given by equation (3) and (4) are different, and the ratios of M_L to M_B are also different), but similar amongst themselves as the correlation coefficient of 84% is also fairly high.

(iv) The difference in the characters of the meanders of the group of 10, (Table-3) and of the group of 7, (Table-4) may be on account of differences in local bed and bank materials, and differences in local silt charges and characteristics which are being examined.

An interesting point of practical significance follow from the present study. The discharge of a stream may be approximately calculated from the knowledge of meander length alone, in absence of other methods, provided the value of the length coefficient C_L of the formula $M_L = C_L \sqrt{Q}$, be suitably taken. From our Laboratory Study, as stated in this paper, C_L had a minimum value of 36 and a maximum value of 78.7, with a mean value of 57.35. Also, from Table 2, average $M_L = \frac{87588}{17} x \, 3.28$ ft. $= 16{,}900$ ft. for the reach of Bhagirathi river considered in this paper. From these,

$$Q = \left(\frac{M_L}{C_L}\right)^2 = \left(\frac{16900}{57.35}\right)^2 \text{ cusecs}$$
$$= 87{,}025 \text{ cusecs.}$$

Though the discharge of a river will vary from reach to reach, the average discharge, over the entire reach of Bhagirathi river considered in this paper, will not be very much away from the aforesaid value (87,025 cusecs) derived with the help of the C_L obtained from our Laboratory Study.

From the above it is clear that extensive studies in the laboratory also on prototype meanders have to be conducted before any conclusive result could be arrived at regarding the formation and behaviour of meandering and braiding of streams.

TABLE—1

Meandering of streams

Sl. No	Q_s c.m./sec. (c. ft /sec)	Q c m./sec. (c. ft./sec)	Q_s / Q	M_L (in ft.)	M_B (in ft.)	M_L / M_B	log (Q_s / Q)	log (M_L / M_B)
1	2 Kg. per hour. 0.00000033 (0.00001154)	0.0052 (0.185)	0.00006239	26.4	8.40	3.14	$\bar{5}.79508$	0.49693
2	5 Kg. per hour 0.00000082 (0.00002885)	0.0127 (0.45)	0.00006412	30.0	9.3	3.22	$\bar{5}.80698$	0.50786
3	3.5 Kg. per hour 0.00000057 (0.00002019)	0.0085 (0.30)	0.00006732	33.70	10.17	3.31	$\bar{5}.82818$	0.52048
4	4.8 Kg. per hour 0.00000078 (0.00002769)	0.0113 (0.40)	0.00006925	40.0	11.50	3.47	$\bar{5}.84041$	0.54033
5	4.48 Kg. per hr. 0.00000073 (0.00002585)	0.0105 (0.37)	0.00006987	40.17	11.92	3.38	$\bar{5}.84435$	0.52763
6	2.45 Kg. per hr. 0.00000040 (0.00001414)	0.0051 (0.18)	0.00007854	34.25	9.50	3.60	$\bar{5}.89509$	0.55630

TABLE—2

A Study of Prototype Meanders in river Bhagirathi

Sl. No.	M_L in proto (in Metres) xi	M_B in proto (in Metres) yi	(xi)2	(yi)2	xiyi	M_L / M_B	Position of meanders in River Bhagirathi
1	5628	3804	31,674,384	14,470,416	21,408,912	1.48	C.S. 31 to C.S. 44
2	6192	4068	38,340,864	16,548,624	25,189,056	1.52	C.S. 37A to C.S. 52A
3	4716	2760	22,240,656	7,617,600	13,016,160	1.71	C.S. 64 to C S. 74
4	4740	3432	22,467,600	11,778,624	16,267,680	1.38	In Between C.S. 81 & 82 to C.S. 92
5	5088	1800	25,887,744	3,240,000	9,158,400	2.83	C.S. 92 to C.S. 100A
6	6516	3204	42,458,256	10,265,616	20,877,264	2,03	In Between C.S. 126 & 127 to C.S. 138/1 & 138
7	5028	2256	25,280,784	5,089,536	11,343,168	2.23	In Between C.S. 153 & 154 to C.S. 162
8	5772	2868	33,315,984	8,225,424	16,554,096	2.01	C.S. 162 to in between C.S.173 & 174
9	7440	2868	55,353,600	8,225,424	21,337,920	2.59	In between C.S. 174 & C.S. 175 to C.S. 187
10	4236	2832	17,943,696	8,020,224	11,996,352	1.50	C.S. 187 to C.S. 196
11	4884	3444	23,853,456	11,861,136	16,820,496	1.42	In between C.S. 190A & 191 to C.S. 200A
12	3360	1488	11,289,600	2,214,144	4,999,680	2.26	C.S. 200A to C.S. 205A
13	4332	2844	18,766,224	8 088,336	12,320,208	1.52	C.S. 227 to C.S. 238
14	5880	3204	34,574,400	10,265,616	18,839,520	1.84	C.S. 243 to in between C.S. 256A & C,S. 257
15	3624	2112	13,133,376	4,460,544	7,653,888	1.66	C.S. 278 to in between C.S. 286 & C.S. 287
16	4728	3672	22,353,984	13,483,584	17,361,216	1.25	In between C.S. 286 & 287 to C.S. 296A
17	5424	1944	29,419,776	3,779,136	10,544,256	2.78	In between C.S. 297 & C.S. 298 to C.S. 310
	Σxi =	Σyi =	Σ(xi)^2 =	Σ(yi)^2=	Σxiyi =		
	87,588	48,600	468,354,384	147,633,984	255,688,272		

M_L = Meander Length
M_B = Meander Breadth
M_L / M_B = 2.83 Maximum, 1.25 Minimum
C.S.=Cross Section

TABLE—3

A Study of Prototype Meanders in River Bhagirathi

Sl. No.	M_L in Proto (in Metres) xi	M_B in Proto (in Metres) yi	$(xi)^2$	$(yi)^2$	xiyi	M_L / M_B	Position of meanders in River Bhagirathi
1	5628	3804	31,674,384	14,470,416	21,408,912	1.48	C S 31 to C.S 44
2	6192	4068	38,340,864	16,548,624	25,189,056	1.52	C.S 37A to C.S 52A
3	4716	2760	22,240,656	7,617,600	13,016,160	1.71	C.S 64 to C.S 74
4	4740	3432	22,467,600	11,778,624	16,267,680	1.38	In between C.S 81 and C.S. 82 to C. S.92
5	4236	2832	17,943,696	8,020,224	11,996,352	1.50	C.S 187 to C.S 196
6	4884	3444	23,853,456	11,861,136	16,820,494	1.42	In between C.S 190A and 191 to C.S 200 A
7	4332	2844	18,766,224	8,088,336	12,320,208	1.52	C.S 227 to C.S 238
8	5880	3204	34,574,400	10,265,616	18,839,520	1.84	C.S 243 to in between C.S 256 A to C.S. 257
9	3624	2112	13,133,376	4,460,544	7,653,888	1.66	C.S 278 to in between C.S 286 and C.S 287
10	4728	3672	22,353,984	13,483,584	17,361,216	1.25	In between C.S 286 and C.S 287 to C.S 296 A
	$\Sigma xi =$	$\Sigma yi =$	$\Sigma xi^2 =$	$\Sigma yi^2 =$	$\Sigma xiyi =$		
	48,960	32,172	245,348,640	106,594,704	160,873,488		

M_L = Meander Length

M_B = Meander Breadth

M_L / M_B = 1.84—Gr. Max., 1.25—Gr. Min.

C.S. = Cross Section

TABLE—4

A Study of Prototype Meanders in river Bhagirathi

Sl. No.	M_L in proto (in Metres) xi	M_B in proto (in Metres) yi	$(xi)^2$	$(yi)^2$	xiyi	M_L / M_B	Position of meanders in River Bhagirathi
1	5088	1800	25,887,744	3,240,000	9,158,400	2.83	C.S 92 to C.S 100 A
2	6516	3204	42,458,256	10,265,616	20,877,264	2.03	In between C.S 126 and C.S 127 to C.S 138.1 and C.S. 138
3	5028	2256	25,280,784	5,089,536	11,343,168	2.23	In between C.S 153 and C.S 154 to C.S 162
4	5772	2868	33,315,984	8,225,424	16,554,096	2.01	C.S 162 to in between C.S 173 and C.S 174
5	7440	2868	55,353,600	8,225,424	21,337,920	2.59	In between C.S 174 and C.S 175 to C.S 187
6	3360	1488	11,289,600	2,214,144	4,999,680	2.26	C.S 200 A to C,S 205 A
7	5424	1944	29,419,776	3,779,136	10,544,256	2.78	In between C.S 297 and C.S 298 to C.S 310
	$\Sigma xi =$	$\Sigma yi =$	$\Sigma xi^2 =$	$\Sigma yi^2 =$	$\Sigma xiyi =$		
	38,628	16,428	223,005,744	41,039,280	94,814.784		

M_L = Meander length

M_B = Meander Breadth

M_L / M_B = 2.83—Gr. Max., 2. 01—Gr. Min.

C S=Cross Section.

REFERENCES

Dutta, A. K. (1961) : *The Role of Grain size in the process of meandering,*—Irrigation & Power Journal, Vol. 18. No, 3, March.

Friedkin J. F. (1945) : *A Laboratory Study of the Meandering of Alluvial Rivers*—U.S. Waterways Experiment Station, Vicksburg. Mississippi, U.S.A.

Indian Waterways Experiment Station, Poona, (1943) : *Annual Reports (Technical),* 1942-43, p. 51.

Schoklitsch– *Der Wasserban,* Vol. 1, p. 143.

Sternberg (1875) : *Zeitschrift Fur Banwesen,* p. 483 et seq.

TIDAL PROPAGATION IN THE HOOGHLY

S. T. GHOTANKAR

Abstract

The navigability of the Hoogly has been deteriorating. This has been due to the hydrological and tidal conditions being in imbalance. The paper discusses the salient features of the tidal propagation and sediment transport and indicates the method of improvement.

Hooghly is the tidal outlet of Bhagirathi, Jalangi and Churni, which are also called the Nadia Rivers (Map at the end). The Hooghly has been navigated since centuries. History shows that the Bhagirathi-Hooghly was once the maincourse of the Ganga. In course of time, former secondary channel gradually developed, thereby relegating the Bhagirathi to a spill channel of the Ganga. As a result, the volume and duration of the flow into the Bhagirathi-Hooghly gradually diminished so that under present conditions the Bhagirathi flows for about 3 months only and significant discharges of 40,000 cusecs occur for 40-45 days. The deterioration of the Bhagirathi-Hooghly naturally affected the tidal propagation. Literature of sequence of changes of tidal propagation in a deteriorating river is scarce. In the case of the Hooghly, however, being navigable, records of survey and tides are available for about a hundred years. From these it is possible to build up a picture of the tidal and channel regimes.

CHANNEL AND TIDAL REGIMES

In an alluvial tidal channel with perennial head water supply, the channel regime is governed by the sediment transport characteristics which result from the balance of quantum of head water flow on one hand and the tides on the other. In the absence of head water, the governing factor is the tidal energy which alone influences the sediment movement.

The channel and tidal regimes are interdependent, so that if the long-term balance of sediment transport is affected, the condition of channel regime affects the tidal propagation which, in its turn, affects the channel regime. Obviously, if the first imbalance is of a deteriorative nature, the vicious circle causes progressive deterioration unless the basic cause is diagnosed in time and preventive measures implemented without delay.

TIDAL ACTIVITY

Tides and their strength depend basically on astronomical forces due to the sun and the moon with some alteration which may be due to meteorological effects. When the sun and the moon are in conjunction, the tidal forces are greater than when they are in quadrature. The former happens twice in a lunar month on full and new moon days while the latter midway between these two phases of the moon. Thus, in a lunar month there are two sessions each of high and low tides. It may happen that while in conjunction the moon may be in perigee that is at the shortest distance in its orbit from the earth. The tidal forces and the tides in this case are higher than other high tides. If, in addition, the sun is on the equator the perigee spring tides experienced are the strongest. This happens on the equinoxes in March and September.

In the Bay of Bengal southerly breeze starts from about February onwards, reaches a peak in the monsoons and ceases in the winter months. Consequent on this the mean sea level at the sea face starts rising from about February and reaches a peak by September and falls back in winter months (Fig. 1).

These factors cause relatively weak tides in winter months, strong tides from February to May followed by a relatively weaker session of tides compared with the March session, but quite stronger than the winter session, culminating again in the September pre-winter session of strong tides.

In the Hooghly in the summer months there being no head water discharge, the session of strong tides governs the channel regime while in September, it is a combined result of head water and tides.

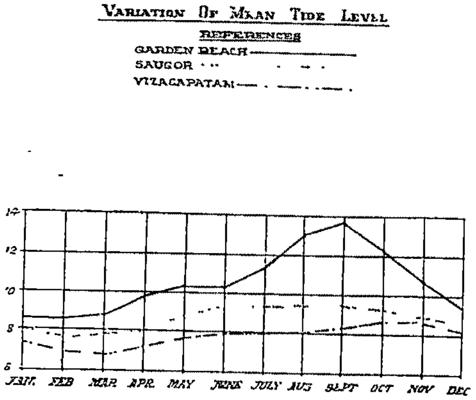


Fig. 1

The ascending node of the moon is the point of intersection of the equator and the moon's orbit where it moves from south to north. This point is a retrograde motion due to which the same relative positions of the sun and the moon repeat after 18.6 years or roughly 19 years. Consequently, the same tidal forces occur after this period. This is called the Metonic Cycle.

TIDAL RANGES

One of the main factors to gauge tidal propagation is the range. However, as discussed before, these change continuously. Consequently, to assess long-term changes it is expedient to work on average of ranges. Further, since the head water supply has progressively reduced and is moreover dependent on the meteorological conditions in the concerned catchments, to examine the changes in tidal activity, it is necessary to consider the tidal ranges in the non-monsoon period.

Records of tides of the Hooghly exist since 1890s. From these the 5-yearly moving average of dry season mean ranges was computed for Garden Reach, Moyapur, Hooghly Point and Balari gauge-sites. Fig 2 shows the plot of the data. It will be seen that progressive increase of Garden Reach ranges started by 1924, at Moyapur by 1934 and at Hooghly Point by 1955.

RESISTANCE TO TIDAL PROPAGATION

In the context of the changes in ranges, it is instructive to discuss the resistance to the tidal propagation by the examination of damping characteristics.

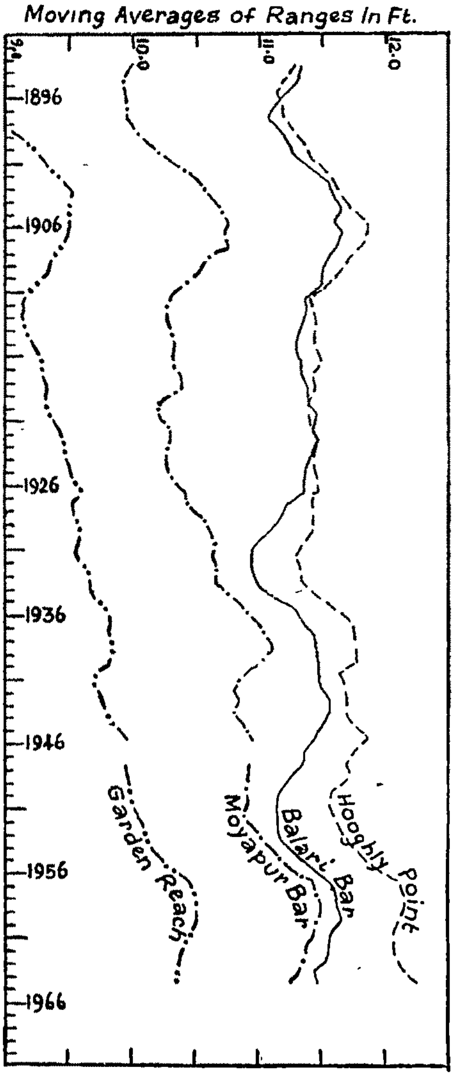
Friction in hydraulics, as is well known, is due to the roughness size of the bed, form of the section and hydraulic parameters R & V—the hydraulic mean depth and velocity respectively. Since R & V are time variant and friction quadratic, in tidal streams, it is not possible to easily determine friction realistically, except by special observation planned for the purpose. For the objective in view, however, viz, assessment of relative changes in tidal friction, it is sufficient to evaluate linearised friction which is about 15 per cent smaller for a tide cycle.

The equations governing tidal motion are—

$$\frac{\delta u}{\delta t}+g\,\frac{\delta \eta}{\delta x}+\lambda u=0 \qquad \dots (1)$$

$$\frac{\delta}{\delta x}(AU)+b\frac{\delta \eta}{\delta t}=0 \qquad \dots (2)$$

wherein the third, i.e., the friction term in (1) has been linearised and the non-linear term $u\frac{\delta u}{\delta x}$ has been neglected. In the equations, U is the velocity, η is the elevation of water surface from the mean, b is the width of cross-section, A is the cross-sectional area at mean level, x is the distance along the channel and t is the



Five Yearly Moving Average of Ranges in the Hooghly
Fig. 2

time variable. The linearised friction co-efficient λ is given by

$$\lambda = \frac{8}{3\pi} g \frac{Qm}{AhoC^2}$$

where Qm is the discharge amplitude, ho is the mean depth and C is the Chezy's co-efficient of friction.

In a channel with mean areas varying exponentially as in the Hooghly so that $A = Ao\, e^{\Delta x}$, it is possible to evaluate friction from the solution of equations 1 and 2.

The solution is

$$\eta = e^{-\frac{\Delta x}{2}} a_1 e^{-\frac{\omega\sigma x}{Co}} \operatorname{Cos} \omega \left(t - \frac{\beta x}{Co}\right) a_2 + e^{\frac{\omega\sigma x}{Co}} \operatorname{Cos} \omega \left(t + \frac{\beta x}{Co}\right)$$

where $\sigma = \frac{\omega}{Co} \operatorname{Sin} \phi$, $\beta = \frac{\omega}{Co} \operatorname{Cos} \phi$

$$Co = \sqrt{gho} \text{ and } \tan 2\phi = 1 - \frac{\lambda/\omega}{\frac{\Delta^2 Co^2}{4\omega^2}}$$

It is obvious that λ the linearised friction co-efficient can be evaluated by evaluating the friction angle ϕ from the observed data of tidal gauges.

It is obvious that when the friction angle tends to 45°, the friction becomes infinite which is synonemous to an effective barrier in the way of tidal propagation.

Application of the theory to the simultaneous gauge data of 1917, 1936 and 1955 which are separated by the period of the Metonic Cycle mentioned earlier, gives results which are shown in Fig. 3. It will be seen that the section of peak losses has been steadily progressing towards Calcutta. This was due to the loss of depth in the river. Thus, the effective barrier has been progressively moving seawards, as a result of which the reflection effects exhibited by progressive rise of ranges have also been moving down. Increased ranges mean increased currents and siltation retards the wave celerity. Thus, the average speed of propagation of the tidal wave between Hooghly Point and Calcutta gradually reduced as shown below :

Year	Average speed of tidal propagation in ft/sec.
1917	28.48
1936	25.34
1955	24.18

EFFECT ON TIDES EXPERIENCED AT CALCUTTA

The changes in the pattern of friction along the channel due to the changes in the channel regime affect the tidal rise and fall of the water level. This can be readily seen from the superposed comparative plot of the 1936 and 1955 tides experienced at Calcutta (Fig. 4). It will be seen that after low water till high water any specific water level was reached earlier in 1955 than in 1936. This is so because in shallow waters the celerity of any phase of the tide depends on the depth and loss of depth retards the progress of the low water relative to higher phase.

These changes in their turn accelerate the time of slacks, besides causing increased strength of flood currents and weaker ebb ones.

CUMULATIVE EFFECT OF CHANGES IN TIDAL REGIME

In the wake of the changes discussed so far, the imbalance between the flood and ebb currents has the effect of influencing the net sediment drift pattern. The accentuated flood currents transport increased quantities of sediment landwards which the ebb is incompetent to carry seawards. This tends to progressively shrink the tidal apex. Further, critical conditions for bore tides develop at lower inlet ranges so that incidence of bore increases. In the Hooghly since 1940s the incidence has increased 100 per cent.

SHOWING VARIATION OF FRICTION ANGLE ALONG THE RIVER

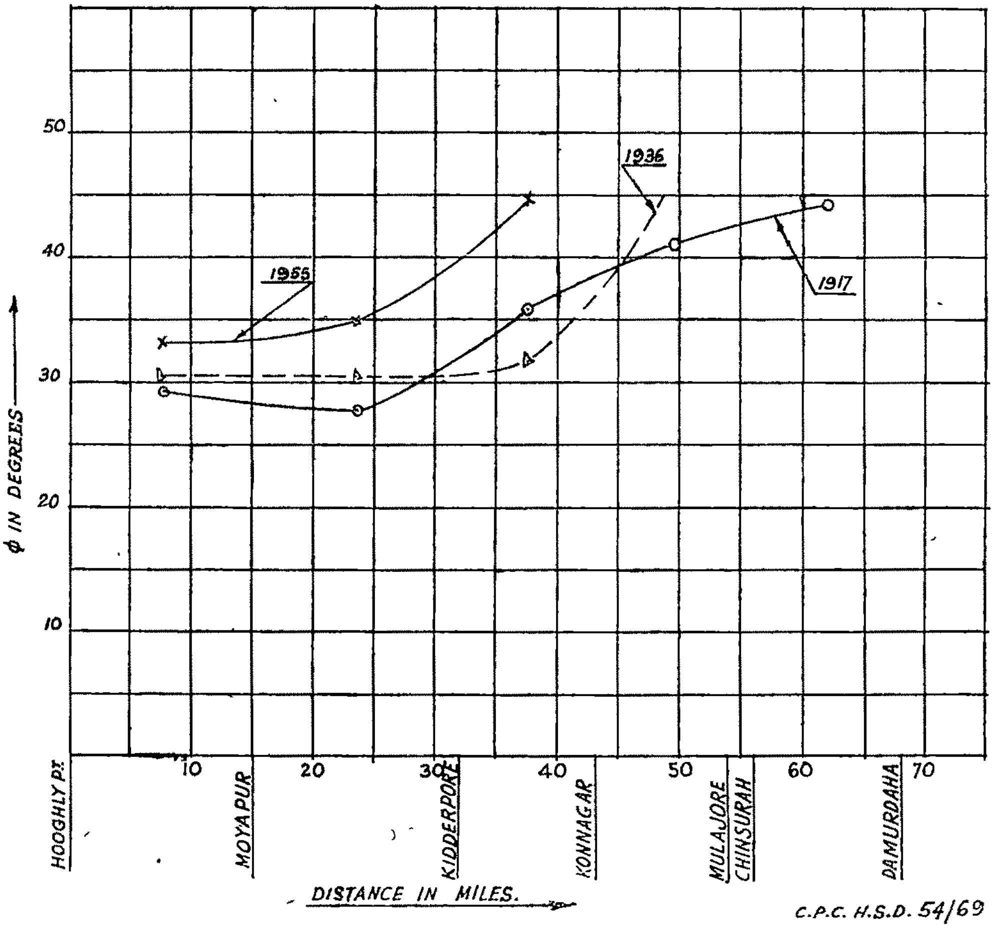


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Fig. 3

As soon as the freshets are on, the sediment drift due to strengthened ebb becomes seawards. However, in totality, the landward drift predominates over a year.

Data of the Hooghly show that in the Hooghly on an average about 7.9 million tons of sand choke up the river system per year.

DISCUSSION

The broad outline of the features of tidal propagtion and sediment transport show that to prevent deterioration it is necessary to improve the tidal propagation and check the landward redistribution. The natural net sediment movement has to be seaward for a channel to maintain itself.

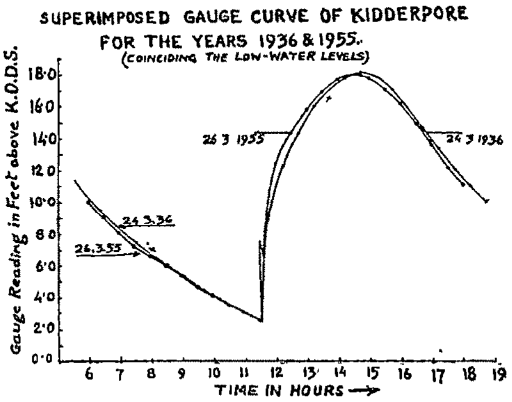

Fig. 4

If measures could be taken so that the tides experienced are simple harmonic, then the sediment movement would naturally be seawards. However, this means the river must be deep in comparison with the tidal amplitude. This by artificial dredging is physically, technically and economically impossible. The other method, therefore, would be to either reduce flood velocities or increase ebb ones. Of these, the former is totally unsatisfactory inasmuch as it means reduction of the tidal flux which is the all important perennial source of energy for the river. The only alternative which is feasible and practicable is to ensure ebb velocities which are sufficiently strong to cause total sediment movement seawards during the ebb which must be in excess of the landward sediment movement during the flood.

INCEPTION AND PROPAGATION OF BORE IN THE HOOGHLY

S. C. ROY

Abstract

An approximate solution of the fundamental equations of continuity and motion, valid at the front of a wave where the bore forms, has been used to define the inception and propagation of bores in the Hooghly. The results obtained from the theoretical considerations compare very well with the prototype observations. By increasing the ebb velocities at low water, the bore at Garden Reach could be substantially reduced.

The propagation of water waves in channels is governed by the 'shallow water' theory. Tidal waves generated in the sea propagate into the estuaries with a celerity of $U+\sqrt{gY}$ in which 'U' is the particle velocity and 'Y' is the depth. The celerity of each wavelet depends upon the values of 'U' and 'Y' which it carries and the celerity increases with 'Y'. Thus when a wave producing an increase in depth moves up a channel, the higher propagation speed at the rear of the wave causes the wave profile to steepen and the wave eventually breaks forming a bore.

Bore tides appear in the River Hooghly during the spring tides. During neap tides, however, no bores occur. Thus for a given channel configuration a certain disturbance producing an increase of depth is capable of producing a bore. Theoretical considerations (Abbott, 1956) provide a condition on the tidal range required to produce a bore, in terms of the geometry and frictional parameter of the river and the propagation of such a bore. The theory is applied to River Hooghly. Such an application serves the purpose of isolating various factors influencing the occurrence of bore and their individual contribution. Resultant effects for any change of any one of the factors can then be evaluated.

THEORETICAL CONSIDERATIONS

Formation of the bore

The fundamental equations governing the one dimensional unsteady non uniform flow in a channel is given by—

Momemtum Equàtion—

$$U_t+UU_x+gY_x-\frac{gU^2}{c^2Y}+gs=0 \quad \ldots\ldots(1)$$

Continuity Equation—

$$(bYU)_x + bY_t = 0 \quad \ldots \ldots \ldots (2)$$

Let 'U' and 'Y' be replaced by u - v and $\eta + y$, where - V and y denote the steady unperturbed values of U and Y and u, η are the small perturbation due to the disturbance. Neglecting the second and higher order terms in u and η (1) and (2) become

$$U_t - (uV)_x + g\eta_x + \frac{2guv}{c^2y} + \frac{g\eta v^2}{c^2y^2} = 0 \quad \ldots \ldots (3)$$

and $(Ybu)_x - (bV\eta)_x + b\eta_t = 0 \ldots \ldots (4)$ the unperturbed equations having been subtracted in each case.

The approximate solutions of equation (3) and (4) are given by Abbott.

$$\eta = y^{-\frac{1}{4}} b^{-\frac{1}{2}} \exp[-\phi(x)]\, f(\tau) \quad . \quad (5)$$

$$U = g^{\frac{1}{2}} y^{-\frac{3}{4}} b^{-\frac{1}{2}} \exp[-\phi(x)]\, f(\tau) \ldots (6)$$

where

$$\phi(x) = \int_o^x (\sqrt{gy} - V)^{-1} \frac{gv}{c^2y} dx \quad \text{and}$$

$f(\tau)$ is given by the relation

$$t = \alpha(x) - \beta(x) f(\tau) + \tau \quad \ldots \quad \ldots (7)$$

with

$$\alpha(x) = \int_o^x \frac{dx}{(\sqrt{gy} - V)} \quad \ldots \quad \ldots (8)$$

$$\beta(x) = \frac{3}{2} g^{\frac{1}{2}} \int_o^x \frac{y^{-\frac{3}{4}} b^{-\frac{1}{2}}}{(\sqrt{gy} - V)^2} \exp [-\phi(x)]\, dx \quad \ldots (9)$$

The approximate solution has been found to be valid near the head of the wave and also at large distances. For this reason, it is appropriate for finding the occurrence of any bore, which may be formed, since in many cases as well in the case of River Hooghly the bore is confined to front region of the wave where the approximate solution is valid even though the solution is wildly out in other parts of the flow.

From the solutions given by (5) and (6) with $f(\tau)$ determined by (7), the criterion whether a given disturbance will produce a bore or not in a certain channel is given by

$$f'(\tau)\, \beta(x) = 1 \quad \ldots \quad \ldots (10)$$

According to (10) a bore will form if $\beta(x)$ exceeds the reciprocal of the maximum value of $f'(\tau)$ for some x. Since β is an increasing function of x, it is, therefore, necessary that

$$\beta(\alpha)[f'(\tau)\max] = 1 \quad \ldots \quad \ldots (11)$$

For a tidal oscillation with η and u measured from low tide position $f(\tau)$ may be taken as

$$f(\tau) = a\eta_o^{-1}(0)\,(1 - \mathrm{Cos}\,\omega\tau) \ldots (12)$$

where $\omega/2\pi$ is the frequency of tidal oscillation and 2a is the range of tide at x=0. Here $\eta_o(o)$ is the value of $y^{-\frac{1}{4}} b^{-\frac{1}{2}}$ at x=0.

By equations (10) and (12)

$$\beta(x) = \eta_o(o)/a\omega\, \mathrm{Sin}\,\omega\tau \quad \ldots \quad 13)$$

The point of formation of a bore occurs when $\omega = \pi/2$ and is given by

$$\beta(x) = \eta_o(o)/a\omega \quad .. \quad (14)$$

Thus for particular tidal range, point of bore formation can be established once $\beta(x)$ is calculated. It is seen that a bore will form in a river if

$$\beta(\alpha) > \eta_o(o)/a\omega \quad \ldots \quad \ldots (15)$$

Height and Path of the bore

Further deductions from equations (5), (6), (7) and (12)[1] given the path of the bore by

$$t = \alpha(x) - a\eta_o^{-1}(o)\,\beta(x) + \pi/2\omega \ldots (16)$$

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[1] For complete analytical treatment refer to Abbott (1956), Green (1837). Whitham (1952 & 1953).

and the height of the bore by

$$\Delta\eta = 2a\eta_o^{-1}(o)\, y^{-\frac{1}{4}}\, b^{-\frac{1}{2}} \exp[-\phi(x)] \operatorname{Cos}\omega\tau_1 \quad \ldots \quad (17)$$

with

$$\frac{1}{\beta(x)} = \frac{2a\omega \operatorname{Cos}\omega\tau_1}{\eta_o(o)(\pi - 2\omega\tau_1)} \quad \ldots \quad (18)$$

APPLICATION TO RIVER HOOGHLY

Details of the River Hooghly

For the detailed application of the theory to the River Hooghly, the origin is taken at the sea face at Saugor (Map at the end). The tidal curve at Saugor is fairly symmetrical, the flood and ebb tide being of about same duration. The breadth of the low water channel is measured from hydrographic survey of the estuary and the river[2] and is shown in Fig. 1; the mean depth y(x) at various stations up the river, for an average spring tide low water are shown in Fig. 2. The assessment of velocity V(x) of the river at low water for an average spring tide is done from many prototypic hydraulic observations.[3] These observations were taken at different locations for various tidal ranges. The variation of V(x) is shown in Fig. 3. The value of the Chezy's co-efficient C is taken as $C = 85\ m^{\frac{1}{2}}/sec$ at the sea face gradually reducing to $C = 75 m^{\frac{1}{2}}/sec$ at the upper end.

Application to theory

Using the values of b(x), y(x), V(x) and C, $\alpha(x)$ and $\beta(x)$ defined by equations (8) and (9) are calculated. Fig. 4 shows

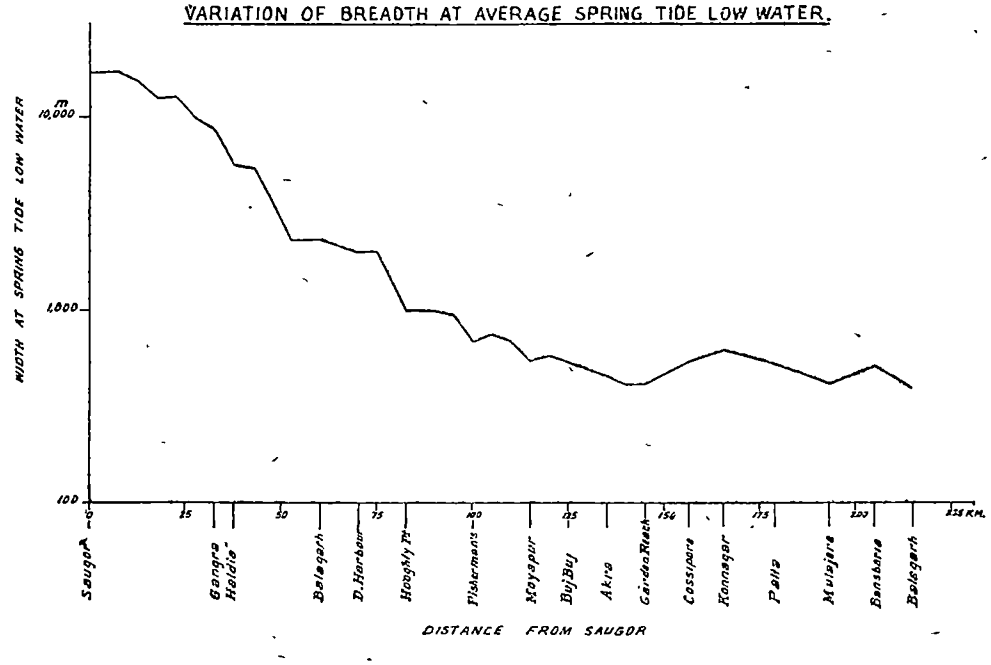

Fig 1

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[2] Hydrographic Survey of the Hooghly—Bansberia to M'Buoy, 1968.

[3] Hydraulic Observations, Technical Reports, 9, 11, 20, 27, 30, 37, 40, 57.

the variation of $\beta(x)$. It may be seen that $\beta(x)$ increases sharply in the reach 75 to 90 km upstream of Saugor—the Eastern Gut, Nurpur-Ninan Reach. Upstream of this reach the rise in $\beta(x)$ is gradual and finally it attains an asymtotic value of $\beta(\alpha) = 19.5\mathrm{m}^{-7/4}$ sec. Using this value of $\beta(\alpha) = 19.5\mathrm{m}^{-7/4}$ sec., the minimum size of tide needed to produce a bore in the river Hooghly can be obtained.

$$a > \eta_o(o)/\beta(\alpha)\omega \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

$$\eta_o(o) = y^{-\frac{1}{4}}\, b^{-\frac{1}{2}} = \frac{1}{220}\, m^{-\frac{3}{4}}$$

$$> 1.66\mathrm{m}.$$

$$\omega = \frac{2\pi}{\tau} = \frac{2\pi}{12.4X3600}\ \mathrm{sec.}$$

From equation (15), it is found that the tidal range must be at least 2a=3.3 m (11 ft.) at Saugor for a bore to form in the Hooghly.

Actual prototype observations show that a bore in the Hooghly is visually detected when the Saugor Range of 3.66m (12 ft.) is reached. With a Saugor Range, varying from 3.32 m (11 ft.) and 3.66 m (12 ft.), the turn of tide at low water is marked by the rush of tide. This rush of tide is also in fact bores of small height.

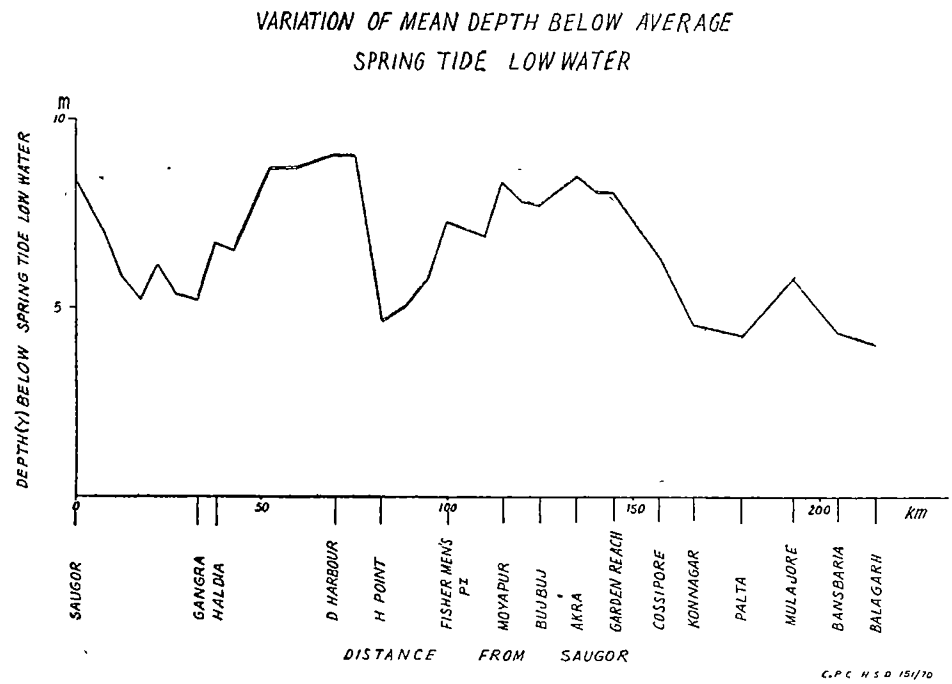

Fig 2

As per this theory the inception of a bore should take place between Diamond Harbour (70 km up-stream of Saugor) and Hooghly Point (82.5 km up-stream of Saugor) when a tidal range of 5.6 m (17 ft.) is attained at Saugor. Such a large range is not normally reached and as such generally bores do not form downstream of Hooghly Point. However, exceptionally high spring tide may attain a 5.6 m (17 ft.) range in which case a bore will be formed below Hooghly Point. In fact, one or two cases have been reported when bore was observed at the Back of the Hooghly.

Thus the application to this theory agrees well with the observed facts in the Hooghly.

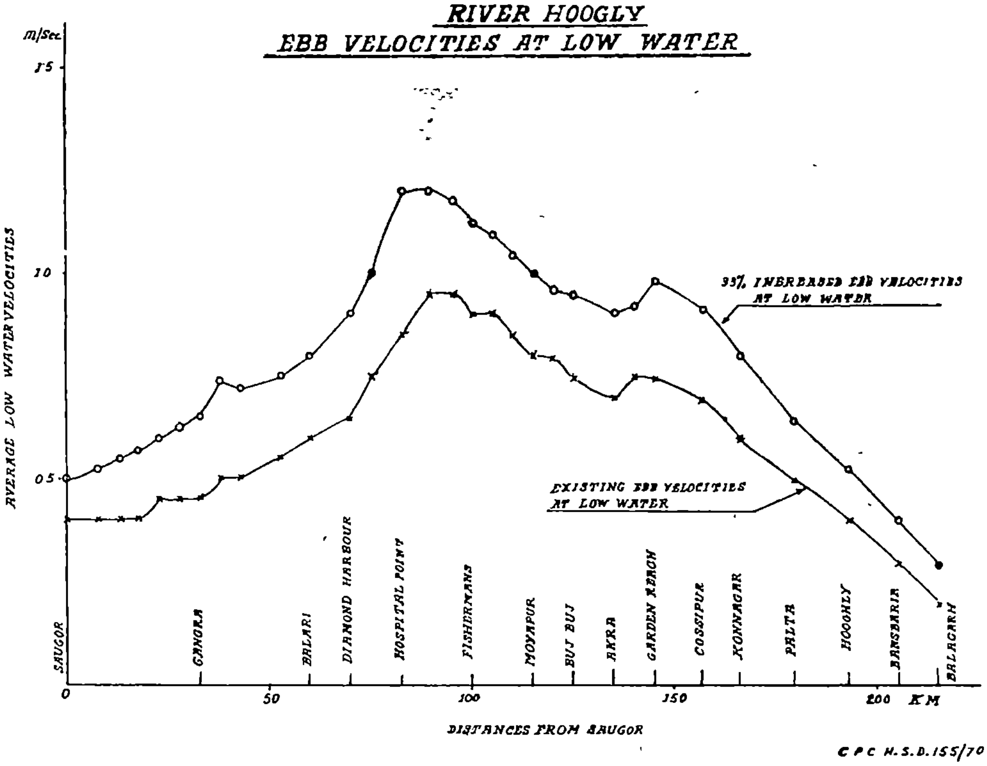

Fig. 3

Height of the bore

The height of the bore is obtained from equations 17 and 18. Fig. 5 shows the bore heights (4η) at different location for a 4·7 m (15.5 ft.) tide at Saugor. From this figure, it is seen that inception of the bore takes place in the reach between Hooghly Point (82.5 km up-stream of Saugor) and Fisherman's (100 km up-stream of Saugor). The maximum height of the bore is reached soon after its inception between Fisherman's and Moyapur (115 km up-stream of Saugor) and thereafter the height gradually diminishes and at Balagarh the bore is fully decayed. The following Table-1 shows the computed height of the bore at different locations together with the observed height.

Fig. 6 shows the computed heights of bore at Garden Reach for different tidal ranges at Saugor. According to this, a small bore in the form of rush of tide should occur at Garden Reach for a Saugor Range of 3.7 m (12.1 ft.). For Saugor ranges of 4.6 m (15 ft.) and over,

TABLE—1

Place	Distance from Saugor (Km)	Height of the bore		Remarks
		Computed for a Saugor Range of 4.7 m. (in m)	Observed on 19.3.69 Saugor Range 4.7 m, (in m)	
Fulta	95	0	0	The observed bore heights have been taken from recording of water level. The height of bore constitute the rise 1 to 5 min. after low water.
Moyapur	115	1.95	1 67	
Buj Buj	125	1.66	1.62	
Akra	135	1.36	1.10	
Garden Reach	145	1.17	1.00	

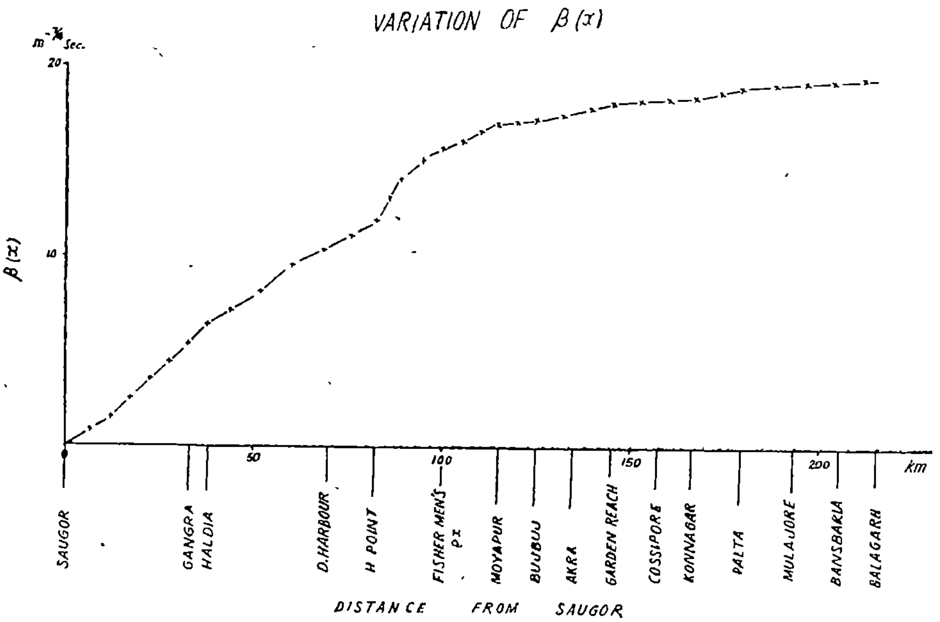

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Fig 4

bore height of 1.2 m (3.92 ft.) to 1.4 m (4.55 ft) would occur—a phenomenon normally observed at Garden Reach.

Path of the Bore

Using equation (16), the path of the bore is obtained. Fig. 7 shows the path of bore in x - t plane. Table-2 below shows the observed and computed travel time of the bore for a Saugor range of 4.7 m.

RIVER HOOGHLY

HEIGHT OF BORE FOR A 4·7m SAUGOR RANGE

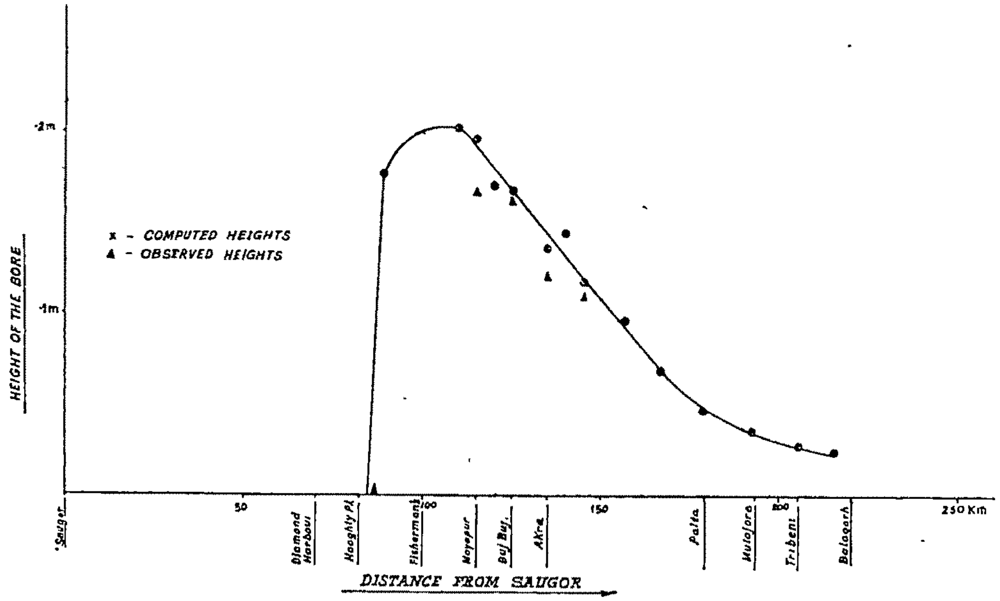

Fig 5

TABLE—2

Reach (in km)	Travel time of the bore between the places in sec.		Remarks
	Computed	observed 19.3.70	
Moyapur— Buj Buj (10)	1100	1260	The observed times are the time difference between the low waters at different locations.
Buj Buj— Akra (10)	1025	900	
Akra— Palta (44)	5550	6540	
Palta— Mulajore (14)	2150	960	

The slope of the line in Fig. 7 gives the celerity of the bore. It may be seen that celerity of the bore does not vary appreciably with distance.

Fig. 6 shows the celerity of the bore at Garden Reach for different Saugor Ranges. Unlike the bore heights, it may be seen that the variation of celerity with ranges is not significant.

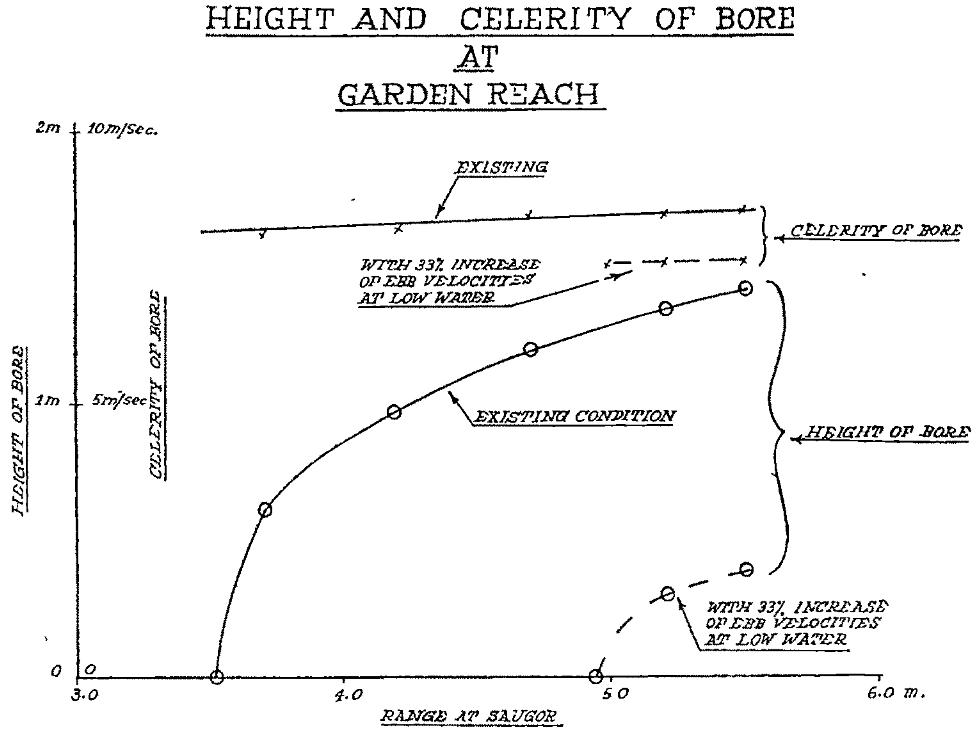

Fig. 6

INFLUENCE OF EBB VELOCITY AT LOW WATER ON THE BORE

It has already been stated that the inception of bore depends on the river geometry, tides occurring at the sea face and frictional parameter. All these factors govern the ebb velocity at low water along the river. This section deals with the influence of ebb velocity at low water on the bore tide.

The ebb velocities at low water are increased by about 33% (Fig. 3) and all other parameters are kept the same. The increase of ebb velocities at low water are purely arbitrary and may not have any physical significance. At least, it is not intended here to detail as to how the low water velocities could be increased or decreased without altering the other parameters.

The effect of this increase of ebb velocities at low water is given in Fig. 6 where the computed heights of bore at Garden Reach for various ranges are shown.

The reduction of bore height at Garden

Reach as compared to the existing condition is significant. In fact, for such a condition, the highest bores at Garden Reach are expected only in the form of rush of tide.

The celerity of the bore at Garden Reach for this increased velocity condition (Fig. 6) does not show any significant change.

CONCLUSION

An approximate solution of the basic laws of equation of motion and continuity has been developed by M. R. Abbott (1956) and applied to River Severn The application of this theory to the River Hooghly shows that agreement with prototype observations are much better than that of the Severn. The inception point of the bore, heights and celerity compare very well with that of prototype.

One of the main advantages of this theoretical consideration is that the individual contribution to the parameters influencing the inception and propagation of the bore can be evaluated.

It is found that a bore will form in a channel with rapidly converging banks with low friction and a small low water ebb velocity. An increase of ebb velocity at low water can diminish the bore heights considerably.

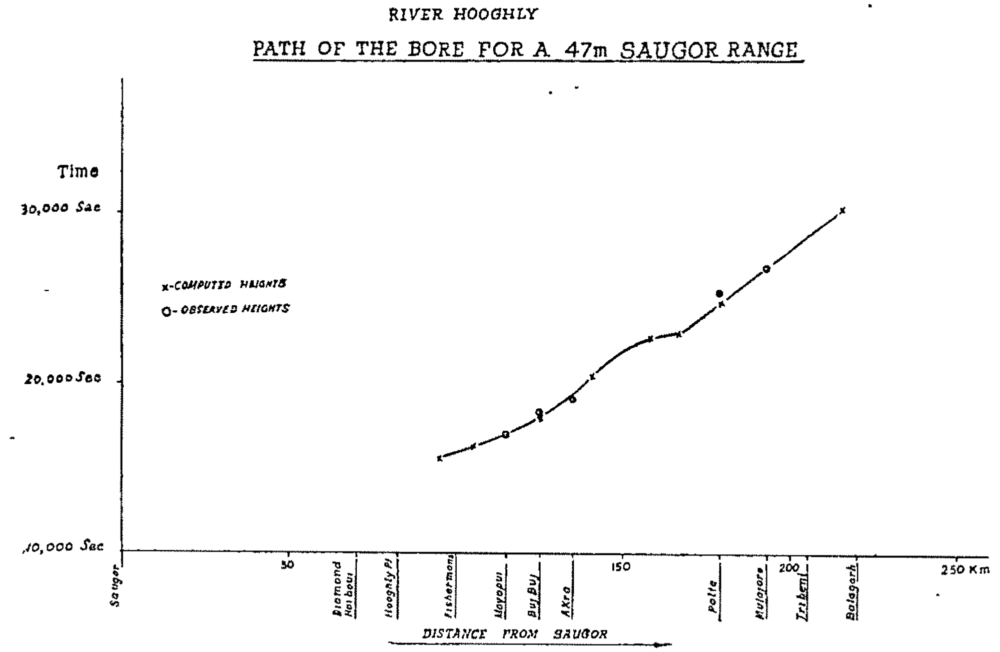

Fig 7

ACKNOWLEDGEMENT

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REFERENCES

Abbott M. R. (1956) : *A theory of the propagation of bores in Channels and Rivers.* Proceedings of the Cambridge Philosophical Soc. Vol. 52, No. 2.

Calcutta Port Commissioners (1968) : *Hydrographic survey of the Hooghly-Bansberia to M'Buoy 1968.* Published by the Marine Deptt., Calcutta Port Commissioners.

Green G. (1837) : *On the motion of waves in a variable canal of small depth and width.* Trans. Camb. Phil. Soc. 6.

Hydraulic Study Dept. : *Hydraulic observations. Technical Reports, 9, 11, 20, 27, 30, 37, 40, 57,* Hydraulic Study Department, Calcutta Port Commissioners.

Whitham, G. B. (1952) : *The Flow Pattern of a Supersonic projectile.* Comm. Pure and Appl. Math. 5.

— (1953) : *The propagation of a weak spherical shocks in stars.* Comm. Pure and Appl. Math. 6.

LIST OF SYMBOLS

$U(x, t)$ = Mean water velocity.

$Y(x, t)$ = Mean depth defined by the cross-sectional area divided by the width at surface.

$b(x)$ = Breadth of the river at Surface.

$S(x)$ = Slope.

C = Chezy's Co-efficient.

g = acceleration due to gravity.

$V(x, t)$ = Steady unperturbed value of U.

$u(x, t)$ = Small perturbation of the values of U due to the disturbance.

$y(x, t)$ = Steady unperturbed value of Y.

$\eta(x, t)$ = Small perturbation of the values of Y due to the disturbance.

$\omega/2\pi$ = Tidal frequency.

$\eta_o(o)$ = $y^{-\frac{1}{4}} b^{-\frac{1}{2}}$ at the sea face.

$2a$ = Tidal range.

SALINITY INTRUSION IN THE HOOGHLY ESTUARY

P. K. CHATTERJEE

Abstract

In an estuary the density gradient due to salinity may be all important in characterising the pattern of flow. Depending on the type of distribution salinity may, in some cases, have a dominant influence on the stability of estuary. The salinity distribution may be also important in the possible utilisation of tidal water.

This paper describes the present salinity distribution pattern of the River Hooghly and changes that would occur for a steady head water discharge. The analysis is one-dimensional. The existing prototype data only provide the transient distribution pattern. The oscillation of the seaward boundary and unknown variation of diffusion characteristics makes the direct solution for a steady condition difficult. However, by making suitable substitution in the basic equation for salinity distribution, the existing transient distribution of the prototype has been utilised to arrive at a steady state solution.

In a tidal estuary the intrusion of saline mass takes place by the process of diffusion and mixing during tidal excursion. This intrusion of salinity in an estuary creates formidable impediment in securing potable water for the cities and metropolis situated on the river. The saline mass coming from the mouth and the pollutants constantly discharged in the river are to be flushed out by the head water discharge. In freshet season flushing of the estuary is no problem, but during dry season the shortage or non-availability of the upland discharge gives opportunity to the salinity intrusion to become progressive.

The river Hooghly is the source of potable water supplied by Calcutta and few other suburban municipalities. The intake point of Calcutta water supply is at Palta on the river Hooghly, situated 15.5 n. miles upstream of Calcutta and was installed in the year 1864. Up to 1935, the maximum salinity at Palta was less than 0.25 ppt (potable limit) and since 1936 it has started rising and in 1965 the maximum salinity at the intake became 3.00 ppt. Along river Hooghly, there are several municipalities which draw water from different places even downstream of Palta. Consumers of these places get highly saline water during the dry season of the year when the salinity front moves as far as Chandernagar (7.2 n. miles upstream of Palta[1]).

The river Rupnarain is meeting Hooghly

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[1] Specific Note No. 44. Hydraulic Study Dept. CPC.

at Hooghly Point (34 n. miles downstream of Calcutta). Tidal flux entering into the Rupnarain from the estuary renders the river water saline and potable water during dry season is not available up to Gadghat 50 n. miles upstream of Hooghly point.

The Haldia complex comprising Dock System, Fertilizer Project, Refinery, is situated on the right bank of the Hooghly (23 n. miles upstream of the sea face at Saugor). When fully developed, this complex will have a water requiremnt of the order of 200 cusecs. Thus, the demand for potable water will gradually spread over a large area along the river Hooghly.

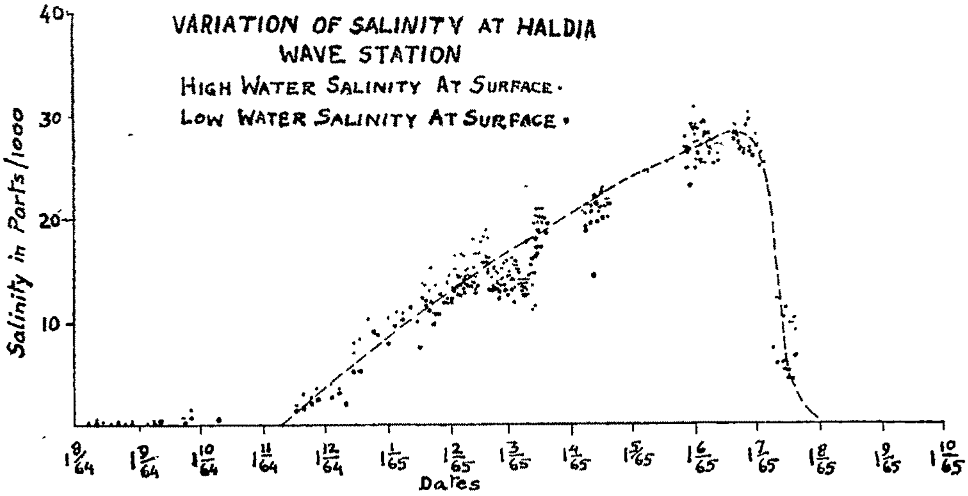


Fig. 1

In this context, it is therefore essential to find out a remedial measure, so that the salinity encroachment in the river Hooghly is retarded during dry season. Farakka Barrage now under construction is expected to solve the problem of the dearth of upland discharge. It would be interesting, therefore, to study the condition of salinity in the Hooghly and the Rupnarain under regulated head water supply. The author has attempted to study the steady state condition, i.e., salinity distribution under different head water discharges.

SALINITY IN RIVER HOOGHLY

The river Hooghly as tidal river has characteristics, which are not comparable to others. In addition to its enormous tortuous length of 186 miles. occurrence of bore tides, high turbulence level, exponential tapering, the salinity profile extends over a great length resulting in a gradient of 20 ppt/ 75 miles at the maximum intrusion length as against 20 ppt/ 52 miles in Delware and 20 ppt/30 miles in Thames (Gole & Vaidyaraman, 1966).

Normal freshet pushes down the salinity front from Mulajore to Balari a distance of about 85 n.miles. During high freshets (above 150,000 cusecs) it is pushed down even up to Gangra and the salinity at the river mouth (at Saugor) falls from the maximum of 34 ppt to 8 ppt. The exact location of the seaward boundary during high freshet could not be located owing to the navigational difficulties during monsoon, but it has been ascertained that in the month of November, the salinity at Eastern Channel Light Vessel (about 40 n. miles below Saugor) being 27 ppt the seaward boundary is, therefore, far below this point.

With cessation of freshet the salinity starts rising in the estuary region. Table-1 shows the movement of salinity front (0.25 ppt) after the cessation of freshet (Fig. 1).

TABLE—1

Month	Position of salinity front	Distance upstream from Saugor in n. mile	Remarks
September	Gangra	18	The positions of salinity front in different months have been located from the observed salinity profiles.
October	Haldia	23	
November	D. Harbour	39	
December	Hooghly Pt.	45	
January	Moyapur	61	
February	Garden Reach	78	
March	Cossipore	86	
April	Palta	94	
May	Mulajore	100	
June	u/s of Mulajore	105	

In all the stations mentioned in Table-1, the salinity fluctuates between high and low water and also between spring and neap tides. The variation between high and low water salinity gets reduced as the salinity rises.

The variation in the vertical at a place is not significant. At Haldia, the salinity changes linearly with time (fig. 1) during dry season. This characteristic is noticeable at all places downstream of Moyapur. Upstream of Moyapur the rate of rise of salinity with time, increases with rise of salinity (fig. 2). The salinities upstream of Akra are very sensitive to weather condition and falls under the influence of local rainfall. With the appearance of freshet the fall of salinity at all the places are very sharp.

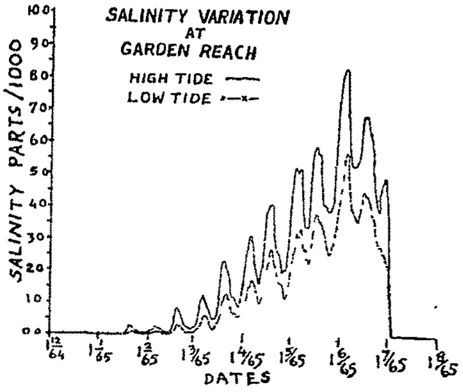


Fig. 2

SALINITY IN THE RUPNARAIN

During the freshet period the river water remains potable and remains so up to the month of December. After the

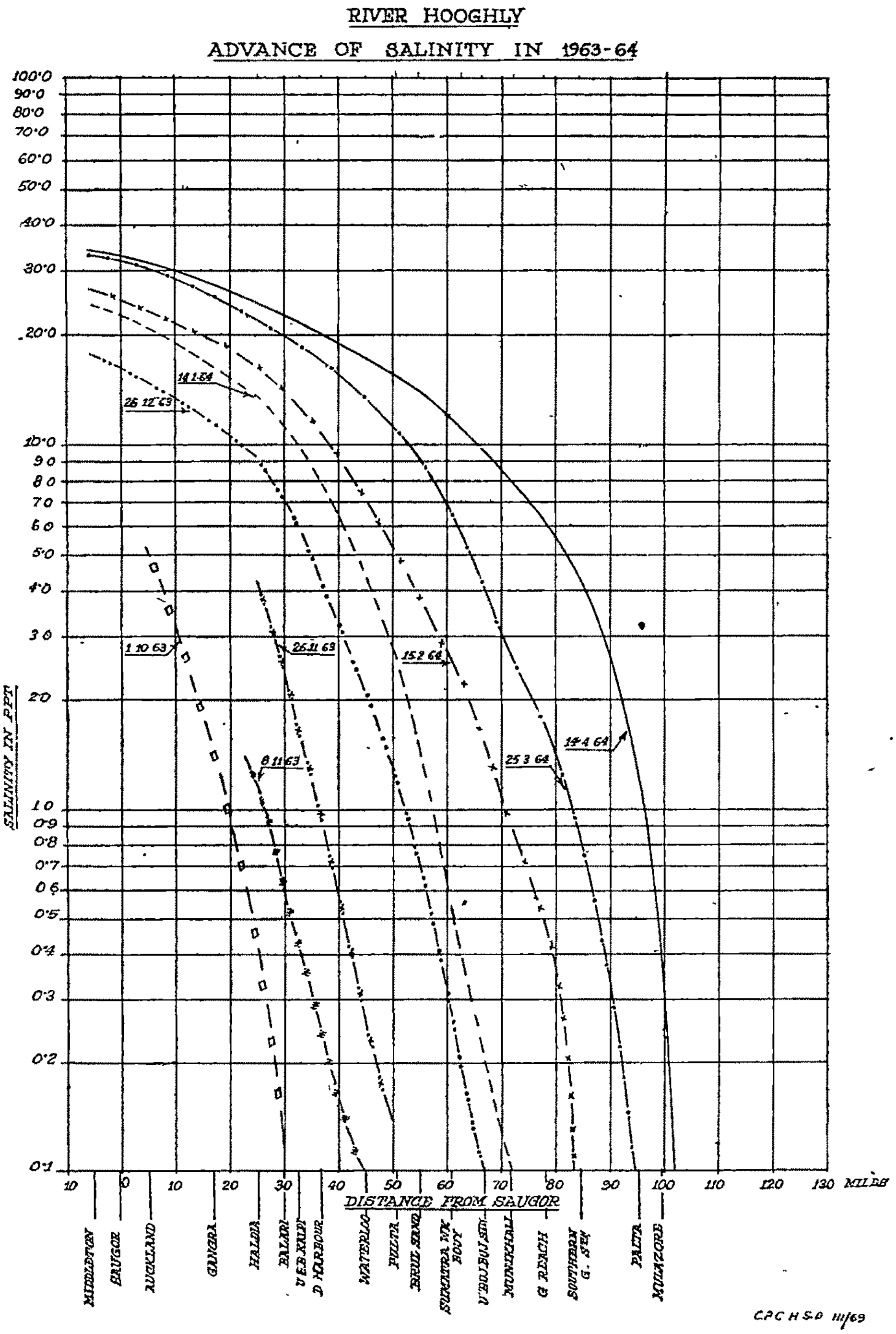

RIVER HOOGHLY
ADVANCE OF SALINITY IN 1963-64
SALINITY IN PPT
100·0
90·0
80·0
70·0
60·0
50·0
40·0
30·0
20·0
10·0
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
14 1 64
26 12 63
1 10 63
26 11 63
8 11 63
15 2 64
25 3 64
14 4 64
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130 MILES
DISTANCE FROM SAUGOR
MIDDLETON
SAUGOR
AUCKLAND
GANGRA
HALDIA
BALARI
U E B KALPI
D HARBOUR
WATERLOO
FULTA
BRUL SAND
SUMATRA WK BOUY
U'BOJ BUJ STN
MUNIKHALI
G REACH
SOUTHERN G. STN
PALTA
MULAZORE
CPC HSD 111/69

Fig. 3

cessation of freshet the salinity front appears at Hooghly Point in the month of December and the Rupnarain salinity starts rising (fig. 3). Within about 2 months' time salinity of 1 ppt is recorded at Bakshi situated about 30 n. miles upstream of Hooghly Point.

THEORETICAL CONSIDERATIONS

The one dimensional equation governing salt transport is

$$\frac{\delta S}{\delta t}+(u_t - u_f).\frac{\delta S}{\delta x}=\frac{\delta}{\delta x} K.\frac{\delta S}{\delta x}$$

where u_t = velocity due to tidal action

u_f = velocity due to upland discharge

S = Salinity at a distance x from the origin

K = diffusion coefficient.

Rewriting the equation as

$$\frac{\delta S}{\delta t}= K.\frac{\delta^2 S}{(\delta x)^2} - \left(u_t - u_f\right)\frac{\delta S}{\delta x} \ldots (1)$$

it is seen that each of the equation expresses the transport in ppt/sec. The 1st term in the right hand side expresses the transport due to diffusion and the 2nd term gives the transport due to tidal mixing and upland discharge. Considering the salinity S, as the mean salinity over a tidal cycle, u_t the tidal velocity over the tidal period can be considered to be zero. Under the steady state condition $\frac{\delta S}{\delta t}=0$. the mean salinity distribution along the river is, therefore, governed by the equation (2) below

$$- u_f.\frac{\delta S}{\delta x} = K.\frac{\delta^2 S}{(\delta x)^2} \ldots (2)$$

Multiplying both sides of the eqn. (2) by the area of cross section A,

$$- Q.\frac{\delta S}{\delta x}= K.A.\frac{\delta^2 S}{(\delta x)^2}$$

$$- QS = K.A.\frac{\delta S}{\delta x} \ldots (3)$$

Solution of eqn. (3) with the proper boundary condition can give now the steady state salinity distribution along the river. The following eqn. (4) shows the solution of eqn. (3) with the boundary conditions mentioned.

$$\log_{10}\frac{So}{Sx} = \frac{\frac{Q}{2.3}}{\int_o^x \frac{\delta x}{KA}}$$

where Sx = Salinity at a point x upstream of sea face

So = Salinity at sea face (34 ppt)

Q = Upland discharge

K = Diffusion coefficient

A = Area of cross section at the point x.

For the following boundary condition

a) Origin at the sea face

b) S = So, at x=o

c) S = Sx, at x from origin

The left hand side of eqn. (4) is a dimensionless quantity and So must be the right hand side. In other words, the denominator of right side must have a dimension of discharge. Denoting the denominator of the right hand side by Qd, the following eqn. is obtained—

$$\log_{10}\frac{So}{Sx}=\frac{Q}{Qd} \ldots (5)$$

From equation (5) So=10.Sx when Q=Qd

$$\text{or } Sx=\frac{1}{10} \times So=\frac{34}{10}\text{ ppt} = 3.4 \text{ ppt}$$

It may be seen that Qd is a function of x. The physical meaning of above deduction is that at a particular place a salinity of 3.4 ppt will be registered when an upland discharge of Qd is applied (3).

The equation (5) justifies that the semilog plot of salinity at a particular place with upland discharge will be a straight line. From this relations Qd is obtained when $S = 3.4$ ppt.

In the river Hooghly, data of salinity at different places during dry and freshet season are available. Selecting the salinity data during rising freshet a semilog plot for different stations were made and a line of best fit for different stations were then drawn. Fig. 4 is a specimen of plot for Moyapur. It may be noticed that the deviation from the average relation between upland discharge and salinity is appreciable. It is easy to understand that variations in the tidal movement, in wind velocity and direction as well as fluctuation in upland discharge also influence the daily observations

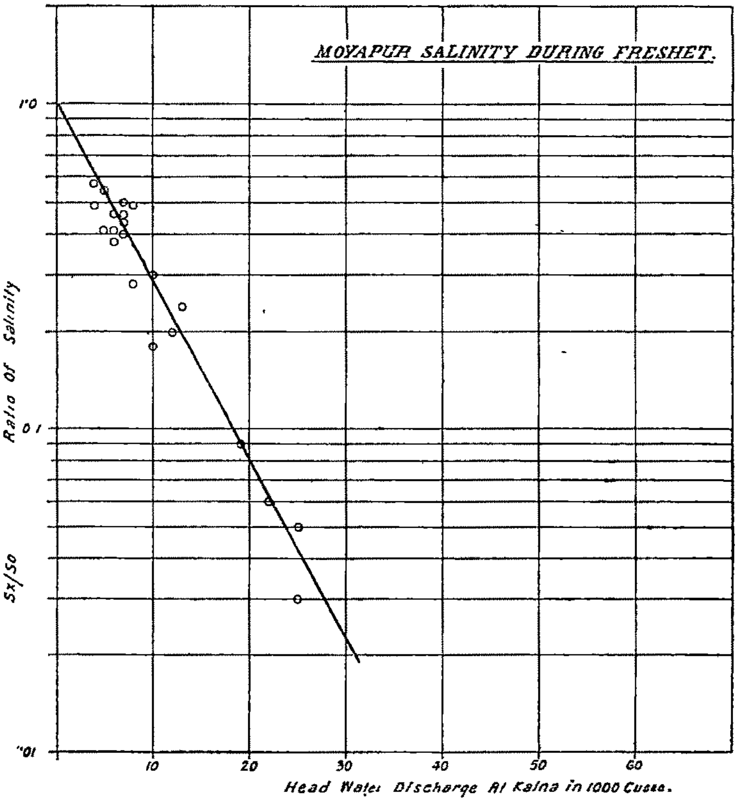


Fig. 4

Fig. 5 shows the distribution of Qd along the river as a function of distance. Applying eqn. (5) salinties at different places for different upland discharge can be obtained. Fig. 6 gives the salinity distribution pattern in steady state conditions under differen upland discharges.

Hydraulic model experiment

To study the effect of upland discharge on the distribution of salinity, model experiments were conducted at Central Water & Power Research Station, Poona. Two sets of experiments were conducted. In the 1st set, when no upland discharge was allowed, the model reproduced the transient salinity distribution as occurring in nature during the dry season. In the 2nd set of experiment 40,000 cusecs of water was allowed and the model was run for a prototype period of about 2½ months after the cessation of freshet. The salinities obtained at the end of this period at various places is shown in Table-2. The same experiment was further continued for a period of 26 days days (prototype time) with a reduced upland discharge of 20,000 cusecs. The salinities at the end of the experiment for different places are also shown in Table-2.

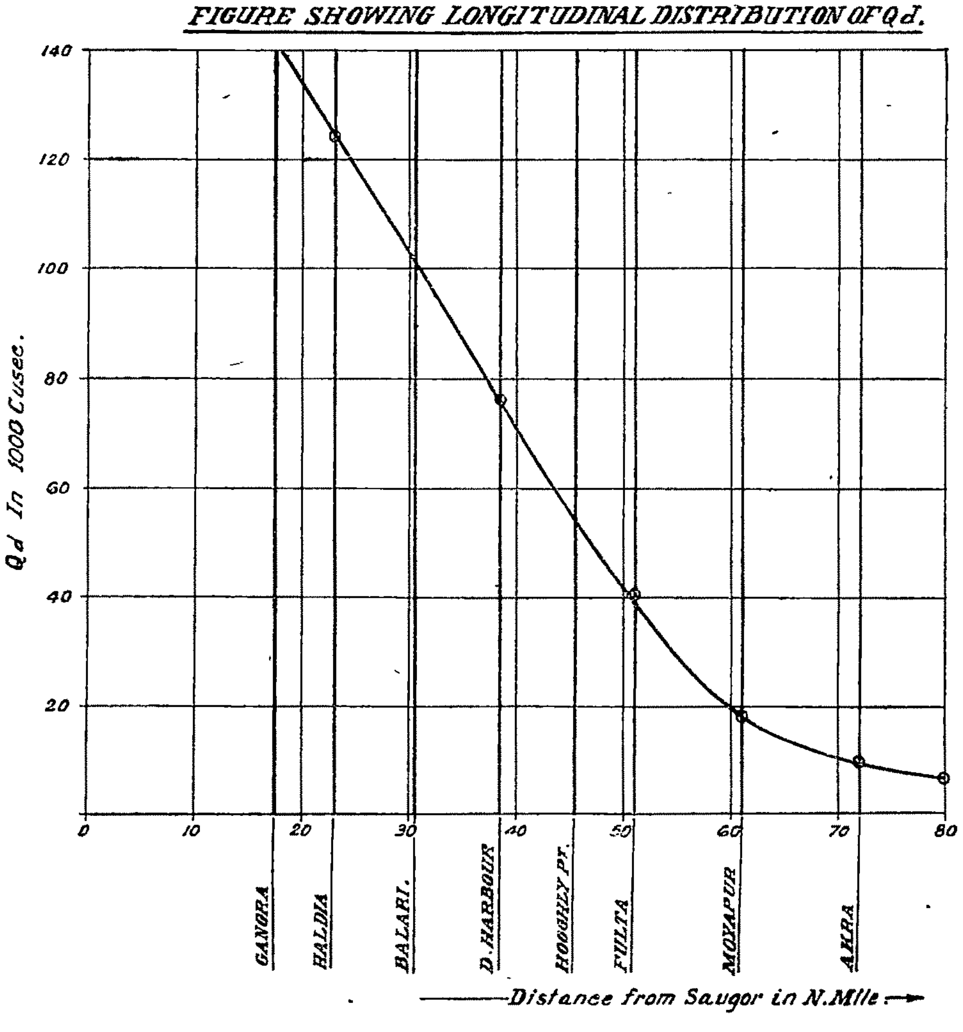
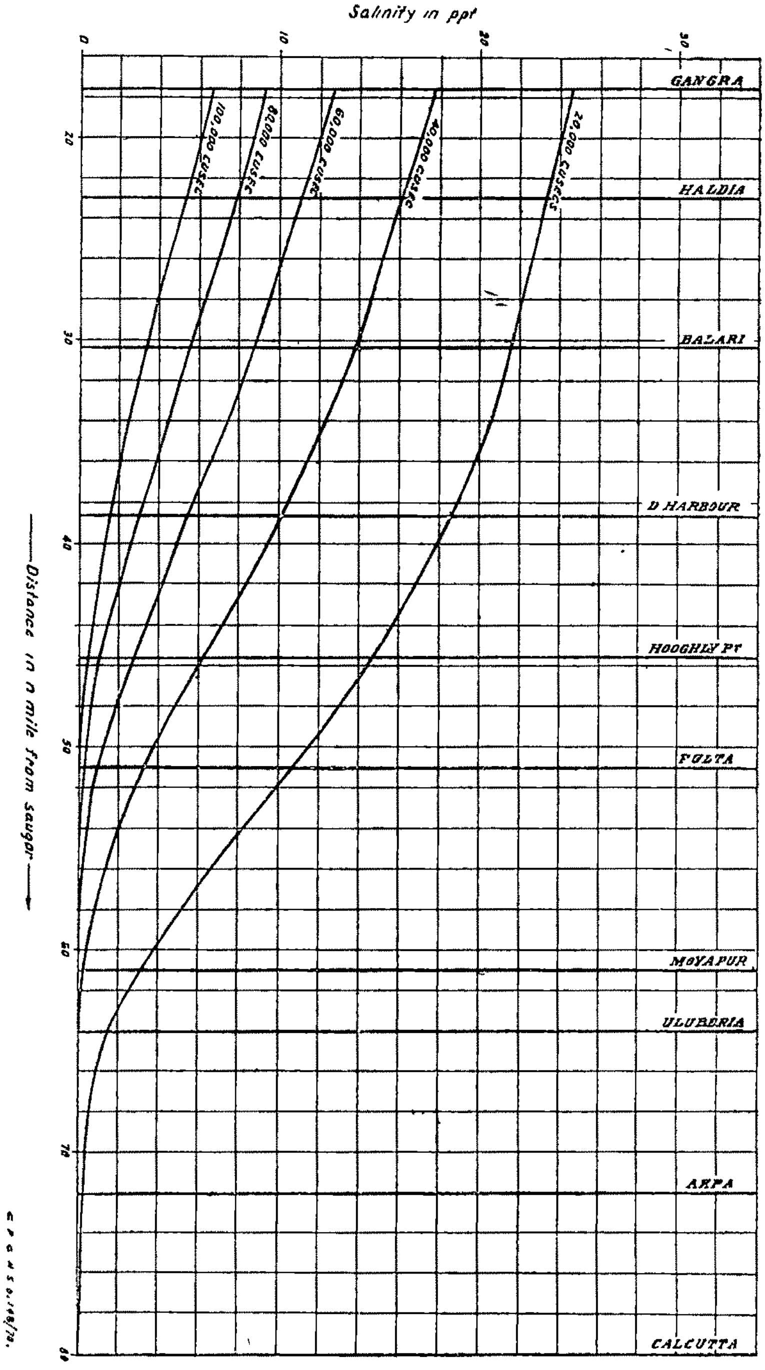


Fig. 5



Salinity Distribution in steady state condition under different upland Discharge.

Fig. 6

TABLE—2

Salinity distribution as obtained by model experiments

Place	Distance from sea face (Saugor) (in n. miles)	Salinity in ppt Experiment II with upland discharge of 40,000 cusecs for 77 days (prototype time)	Salinity in ppt Experiment II -continued for a further period of 26 days (prototype time) with a reduced upland discharg of 20,000 cusecs
Calcutta	79	Nil	Nil
Moyapur	60	0.3	0.4
Hooghly Pt.	45	2.0	3.8
Diamonal Harbour	37	7.5	9.0
Haldia	21	16.0	18 8

RESULTS

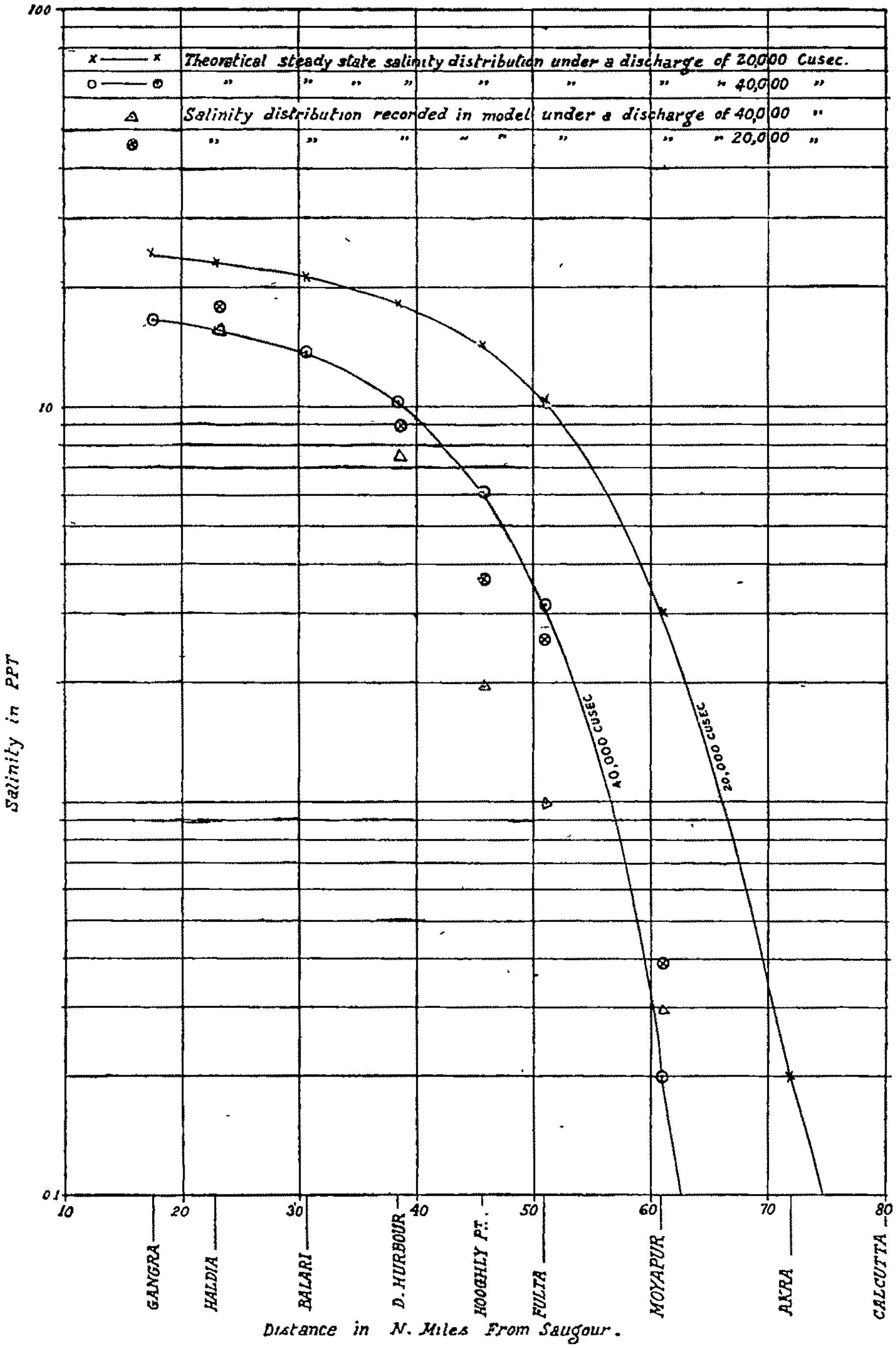
A comparison of the salinity distribution obtained from the theoretical consideration and that of the model experiments is shown in fig. 7. It may be seen that the experimental salinities registered always a lower value than that obtained from theory. Also the agreement between theoretical and experimental value for the 40,000 cusecs upland discharge is better than that of 20,000 cusecs.

It may be mentioned here that a large number of tides are required to be run in the model to attain the steady state condition. In this context, the conducted experimental results show the transient salinity distribution. The 2½ months period (prototype) for which the 2nd experiment with 40,000 cusecs was conducted was not sufficient enough for the salinities to reach a steady state. Although it seems that the steady state condition was nearly reached.

The period for which the experiment No. II was extended with reduced discharge of 20,000 cusecs falls very much short of the time required for attaining the steady state distribution. Had this experiment been continued for a further prototype period of 2½ months, or so, the experimental results would have possibly shown the distribution as obtained from the theoretical consideration.

CONCLUSION

Considering the one dimensional salinity distribution, theoretical salinity distribution under different upland discharges have been obtained for a steady state condition. Some experimental results were available to check the validity of theoretical consideration and the comparison of the theoretical and experimental results show that such a theoretical consideration could be employed for determining the steady state salinity distribution.



Theoretical Steady State Salinity Distribution.
Fig

ACKNOWLEDGEMENTS

The author is grateful to Dr. S. K. Bhattacharya, Chief Hydraulic Engineer, Calcutta Port Commissioners, for his encouragement and also to Dr. S. C. Roy, Assistant Hydraulic Engineer, Calcutta Port Commissioners for the guidance in this study.

REFERENCES

Calcutta Port Commissioners (1969) : *Determination of upland discharge from Salinity Intrusion*, Specific Note No. 44. Hydraulic Study Department, pp 1-9.

Gole, C. V. and Vaidyaraman, P. P. (1966) : *Salinity distribution and effect of fresh water flows in the Hooghly river*, Proc. of 10th Conference on Coastal Engineering, Vol. II.

Santema, Ir. P *Water Management in the tidal reaches in the Rhine and Meuse after completion of Delta Works*, Note published by Rijkswaterstat Service of the Delta Works, The Hague.

NAVIGATION IN A TIDAL RIVER WITH PARTICULAR REFERENCE TO RIVER HOOGHLY

B. N, BANERJEE

Abstract

Navigation in a waterway is generally governed by the depth of water, channel configurations, flow patterns, weather conditions etc. In addition to these, navigations in a tidal waterway is also affected by tidal variations, storm serges, occurrences of bore tides and frequent variations in channel depths. For such reasons, stupendous efforts have to be made for the upkeep of ship navigation in tidal river, particularly in the River Hooghly.

The author reviews the various causes which makes navigation in a tidal way difficult and the problems confronting the River Hooghly and generally the Port of Calcutta.

Abounding hinterlands and navigable conditions from seaward of a number of wellknown rivers have laid the foundations and their subsequent developments of a number of major riverine ports in various parts of the world. Mississippi with New Orleans, Yangtze with Shanghai and Nanking, Thames with London, Hudson with New York, St. Lawrence river with Quebec and Montreal, Elbe with Hamburg, Wesser with Bremen, Rhine with Rotterdam and Hooghly with Calcutta, may be cited as typical examples. In certain regions, the absence of a broken coast line suitable for developing natural harbours, enforces the seeking of a harbour site within the sheltered reaches of a river—a factor which had given birth to the Port of Calcutta.

In this paper endeavour has been made to analyse and discuss the salient and peculiar features of tidal waterways. The approach to the subject will be pragmatic and problems will be discussed at the level of experience and expediency without serious academic investigations into scientific causations.

WHAT IS TIDE

The effect of combined attraction of the sun, moon and planet, is to introduce a disturbing force which tends to distort the earth ellipsoid. The bulk of the earth is a solid body, the mean gravitational force is in balance with the mean centrifugal force, but the latter remains constant, whereas the gravitational pull between moon and earth decreases on the side away from the moon and increases on the side nearer the moon. There is thus a distortion of the water surface due to the unbalanced gravitational attraction. This produces a flow of water towards the points which are both nearest and farthest from the moon and this is called tide. Two simultaneous regions of high tide and two regions of low tides occur over the surface of the earth due to the reasons enumerated above.

Earth rotates about its own axis once in 24 hours while the moon completes its orbit round the earth in approximately 28 days. The plane of rotation of the earth is inclined to the plane of rotation of the moon. These rotations affect the daily tides in the waters of earth. When the moon is over the equator, its pull will produce two tides more or less of similar magnitude at any point on earth during each rotation of earth —this produces semi-diurnal tide. When the moon is vertically over the points either to the north or to the south of the equator, the tidal pull on the side nearest to the moon will occur in one hemisphere while the tidal pull on the side farthest from the moon will occur once a day in the other hemisphere. In each hemisphere, therefore, one tide a day will be stronger than the other—this is diurnal variation of tide.

The situation caused by the sun is identical in principle with that caused by the moon, with the exception that earth rotates round the sun once in approximately 365 days. In spite of its large mass, the tidal pull due to the sun is only about 0 46 that of the moon, because the distance from sun to earth is so much greater than the distance from moon to earth and the average distance from sun to earth is about 389 times the average distance from moon to earth, whereas the mass of the sun is 27 million times the mass of the moon.

What are flood and ebb tides

Flood tide is the movement of water which comes in from sea face inward till it reaches its highest altitude and thereafter it starts receding. This particular time is called that of ***high water.***

Ebb tide is the movement of water which flows downstream towards sea in otherwords the level starts falling and when it reaches its lowest depression and thereafter starts rising or meets the incoming flood is the moment of *low water.*

THE BEHAVIOUR OF TIDAL WATERWAYS

Tidal rivers and their estuaries are noted for their apparent instability. Usual tidal rise and fall in an open sea outside an estuary mainly depends on the ocean tides and are determined by celestial forces and the geometry of the ocean beds in relation to the rotating earth. Its effect will, therefore, be closely predictable over long periods of time. If there are large and extensive patches of shoals outside the mouth of the estuary, the tides there will be affected by propagation over shallow water which will vary according to the build up of the shoals.

FLOW OF WATER AND SEDIMENTS FROM THE TRIBUTARY OF RIVERS INTO ESTUARY

The supply of water and sediments by rivers is the main factor which determines the behaviour of the estuary. The interaction of river flow and tides must be so, that the sediments are carried towards the sea or disposed of by land reclamation processes at the same rate that the material is driven into the tidal rivers.

What is an Ideal Estuary

An estuary can be defined as ideal (Fig. 1) which widens appreciably in its approach to the sea under the influence of divergent path of flood and ebb currents. It is implicit in this definition that the currents are free to form channels through alluvial deposits. In other words, an ideal estuary that is in regime, is, therefore the channel in alluvium through which water and solids brought down by the feeder rivers, are carried to the sea. Tidal propagation in the estuary remains unchanged over a period of years. The rate of solids which enter the estuary is equal to the rate of solids which leave it seawards. The following two sectors are essential for an ideal estuary.

(a) Tidal range is small compared to stream depth i.e., river flow is preponderant.

(b) Tidal range is of the same order as the mean depth over bars are crossings in the river.

What is a Typical Tidal River

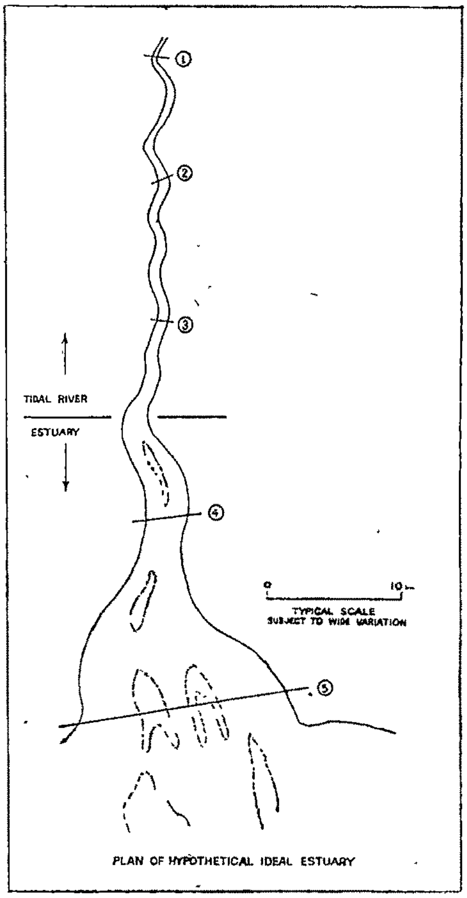


Fig. 1

The divergence of ebb and flood currents would become significant and will lead to some seasonal fluctuations in the position of deepest water at the crossing of points of inflexion of the channel (Fig. 2). A tidal river would gradually widen to accommodate the flow necessary to bring about the tidal rise and fall at points further upstream. Tidal range may reach its maximum somewhere in this part of the river at or near the point where the river widens into the estuary. Up to this point, the bed level would have been gradually falling. Seaward to this, the average level may tend to remain almost constant or even to rise slightly towards the mouth of the estuary. Mean water level, on the other hand, would fall towards the sea, the slope becoming small in the estuary but always downwards to the sea.

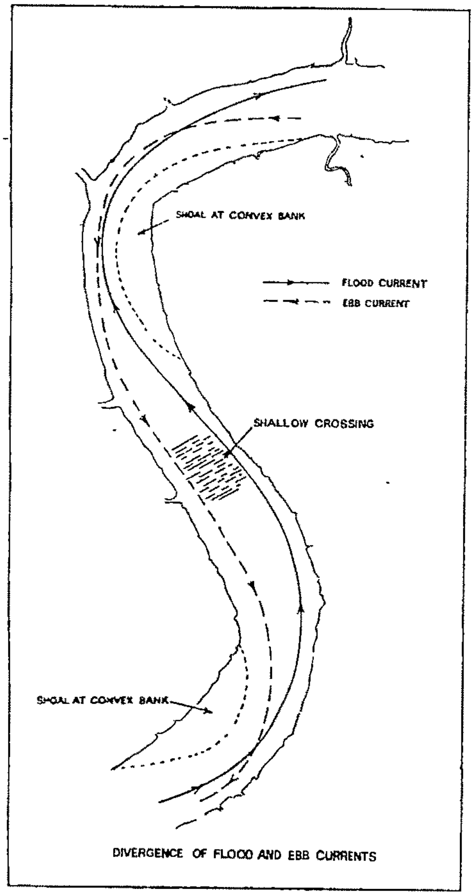


Fig. 2

Divergence of flood and ebb channels eventually cause the meandering paths to diverge within river banks. When this occurs, the tidal river meets the estuary which is in fact, defined as the part of a tidal river in which the bank widen appreciably towards sea.

Tidal flow always increases towards the sea because the total net tidal volume of water upstream of a cross section at anytime has to enter and leave through that section.

Tidal Current

The tides have little effect in sediment transportation along the coast. But the case is quite different when we come to tidal rivers and in estuaries. The flow pattern, the channel geometry and the transport of sediments essentially depends upon the tidal current.

The following are the maximum and minimum tidal ranges in three major ports on the Eastern coast of India—

	Max.	Min.
i) Madras (Tamilnadu)	5 ft.	10 inches
ii) Visakhapatnam	5.4 ft.	2.4 ft.
iii) Hooghly Estuary	17 ft.	3 ft.

The strength of the tidal current varies with the slope of the sea bed and also with the seasonal variations. The maximum recorded velocity in the Hooghly estuary had been of the order of 200 cm/sec.

PARAMETERS WHICH GOVERNS THE NAVIGABILITY OF A CHANNEL

a) Depth b) Velocity c) Width

Nabigability is often concerned with the depth and velocity at shallow sections. Usual features of streams are deep and shallow. Meandering channels for example, characteristically are deep at the concave side of bends and shallow at the cross over between bends as illustrated in Fig. 3, which shows the variation in depth about a typical meander on the River Hooghly. It may be said straight uniform channels rarely exist in nature. The beds of straight reaches are irregular because the thalweg wanders to and fro across the channel, simulating the pattern of a meandering water course.

It has been seen from experience, that

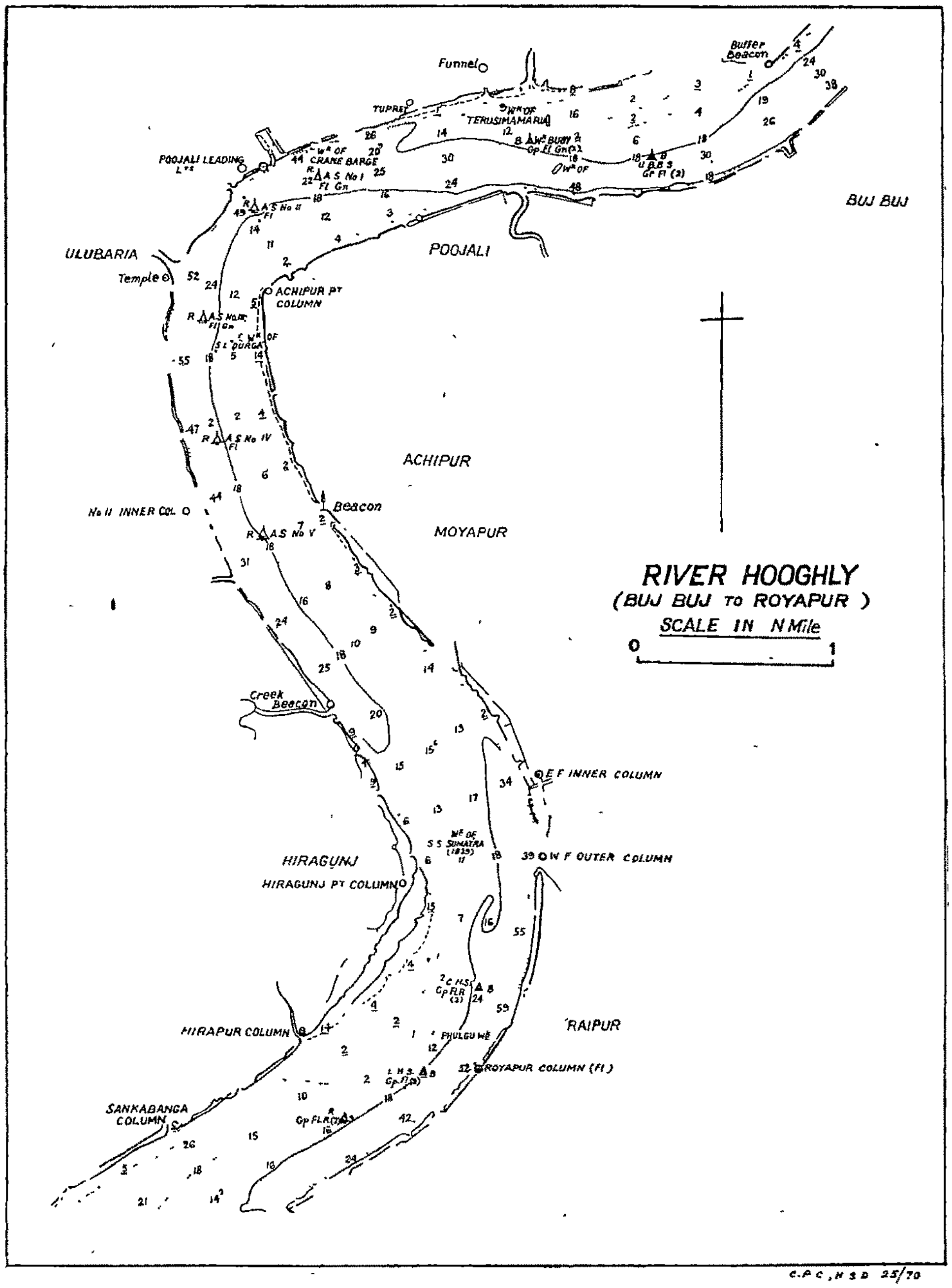


Fig. 3

too little of depth or too much of tidal velocity prohibits navigation. This is where the natural harbours scores over riverine ports.

Width is not usually limiting factor in navigation in comparison to depth and velocity though it has its contribution for improving the navigability of a channel. Narrowness limits the pliability of vessels as sufficient maneouvring space is essential for easy handling and meeting of ships.

RIVER NAVIGABILITY

A vessel while in motion has to withstand the following resistances—

(a) Resistance against the hull which increases as the vessel moves on a shallow water. The motion of the vessel induces a reverse flow in the confined space between the ship bottom and the bed which adds to its resistance. In fact, ship movement tends to lower the pressure field surrounding the hull. The motion induced in the water creates kinetic head at the expenses of potential head and the vessel is lower than when at rest. This causes a change in trim —usually a settling of the stern and rise in the bow of a ship. Both effect, sinkage and change in trim collectively called SQUAT—result in an increase in draft and a loss in bed clearance in shallow water. The squat is usually greater in shallow depths than deep, because the decrease in bed clearance tends to increase the reduction in potential head resulting in greater squat. Squat increases with speed.

(b) Resistance due to slope drag is caused when the vessel is moving upstream. The component of the force due to the weight of the vessel acting along the slope as it is moving.

(c) Resistance due to river bends are experienced when vessels are negotiating a bend, she has to withstand the centrifugal force which is directly propoitional to the square of the vessels speed and inversely proportional to the radius of curvature of the bends. Measurements reported by Leopold and Wolman (1960, p. 774) indicate that the radius of curvature of meanders averages about 2.3 times the channel width. So that as a vessel proceeds upstream and the channel narrows, the power so expended increases. Although the loss of power acts further to limit attainable speed in channels of decreasing dimensions, the loss is not sufficiently great in comparison with other factors to be controlling.

WIND

Wind is a dynamic agent which controls the magnitudes at direction of sand and sediment and other physical agents —hence causes a significant change in the distribution of sand along the coastline.

The prevailing monsoons along the Eastern Coast of India, are Northeast (NE) and Southwest (SW) monsoons. The most dominent wind prevails during the SW monsoon, which begins about the mid-June and continues till mid-October. Southwesterly direction wind blows during the time. The Southerly components and the prevailing wind changes to Northerly component by the end of October and by January, NE'ly wind becomes prevailing. From February to May, the NE wind is replaced slowly by southerly wind. And thus the cycle goes on in this fashion. In 1969, the average wind velocity recorded during SW monsoon were :

in estuary of the Hooghly	— 12.2 km.p.h.
at Puri	— 22 km.p.h.
at Tamilnadu	— 15.8 km.p.h.

WAVES

Wave is another important factor which controls the general configuration of shore line. It is the primary source of energy available at a shoreline for moving sediment. The magnitude of sand transport depends on the length of the wave, its amplitude and depth of the continental shelf. Wave height at the mouth of the Hooghly estuary normally ranges between 0—2 ft. Maximum intensity is attained during early part of SW monsoon when waves higher than 6 ft. have been recorded During cyclone and storms, waves are much higher. Wave period normally ranges from 5 to 7 seconds and during SW monsoon it increases to 12 to 13 seconds.

The east coast of India has frequent cyclone storms of exceptional strength and violence. Major cyclonic storms are experienced during the transition period of Southwest monsoon to Northeast monsoon. This will bear testimony ; year before last October/November storms which caused havoc at Hyderabad and Tamilnadu, took a toll of nearly 30,000 lives and rendered many homeless. From the available data of the past, most of the severe storms crossing the east coast were accompanied with storm surges i.e. abnormal rising of water against shoreline being produced by the strong wind stress and large difference in atmospheric pressures.

The report of the Indian Meteorogical Dept. (1964) showed that the total number of cyclonic storms that formed in the Bay of Bengal during last 70 years was of the order of 314. Out of which severe intensity occurred more than one hundred times. The turbulence produced by such severe storms accompanied by huge waves is one of the powerful agents responsible for large scale littoral drift, coast erosion and under water accumulations. An example is cited here. The cyclone of 3rd November 1966 off Madras coast which had recorded a maximum wind velocity of 104 km. p.h. had caused extraordinary high water on the coast and had totally smashed 3 ships and grounded few. It is gathered the total erosion of 21,07,198 tonnes of sand was estimated near the harbour as a result of this cyclone.

PORTS OF NEW YORK, LONDON AND CALCUTTA

Enormous development has been taking place in world trade and for such purposes, ships of larger size and draft with more speed is the clarion call for the nation. One of the major problems which is confronted in estuaries and rivers—phenomenon of shoaling, and consequent fall in depth. It would be interesting to study briefly the comparative characteristics and the problems of three well known ports viz., New York, London and Calcutta. The following table should cast a better perspective.

The Thames and the Hooghly estuaries have similar tidal ranges. But the Thames has a higher neap range compared to the latter. The Thames has also a perennial head water supply. Some localities in the Thames are prone to accrete due to mud deposits. It has been stated that the shoaling problem is due to attempts in maintaining greater depths inconsistent with hydraulic parameters and without any corresponding constrictions in width. In the

.Comparative study of few tidal rivers

Port	Location from sea (in miles)	Tidal length (in miles)	Tidal Range (in ft.)	Least on navigable depth (in ft.)	Flood time & max. velocity in hrs. ft./sec	Ebb time & max. velocity in hrs. ft./sec	Problems
1) New York (Hudson River)	41	100	S-5 N-4	30	6.25 4	6.25 5.1	Lot of shoaling occurs between Battery and George Washington Bridge; 76% of the sediment is contributed by upland flow; otherwise the navigation channel is fairly good.
2) London (Thames River)	45	70	S-16.7 N-10.9	27	6.25 5.8	6.25 5.1	The estuary is generally in good condition. Extensive shoaling is, however, experienced in the Mud Reaches between 35-40 miles from the mouth.
3) Calcutta (Hooghly River)	80	185	S-16 N- 7	11	5 11	7.50 11	Source of shoaling material is from upland supplies during freshets. Hardly any upland supply during dry seasons. Preponderant flood tide prevents the journey of the shoaling materials seaward.

S denotes — Spring tide
N denotes — Neap tide

Hooghly, head water supply or say, upland supply is restricted to 3 months a year during which huge quantities of sand are brought down, all of which cannot be transported to sea.

The Hudson River's problem of shoaling between Battery and George Washington Bridge can be attributed to the predominance of flood current at the bottom of the reach, regardless of the magnitude of the fresh water run off. This phenomenon has been caused due to constricted waterway at the bridge.

RIVER HOOGHLY

The river Ganga rises in the perennial snows of the Himalayas at a place in Tehri-Garhwal at an elevation of 13,800 ft. above sea level. Little downstream from its source, the water begins to be turbulent over rocks and shallows. It is so violent that boating is impossible there. The landscape is delightful and at points where its tributaries come in, Hindu places of pilgrimage have been found ; after following for another 200 miles the river leaves the Himalayas at Hardwar and then it flows through the hot plains of Northern India. At Allahabad it meets the Jamuna It runs in a generally eastern direction along the southern side of its central valley. Skirting the northern edge of peninsular India, and receiving successively as affluents on the left bank the rivers Gomati, Ghaghara and Gandak, draining the Himalayan southern slopes, and on right bank the important Sone river. Just above Sahibganj, the Kosi joins it from the north and the Ganga there sharply rounding the outlaying fringes of the Rajmahal Hills, follows a general southeasterly course. After passing Rajmahal, it enters on its deltaic career, giving off its first effluent, the Bhagirathi at Giria, about 34 miles above Rampur Boalia. A few miles downstream, the Ganga receives its last tributary, the Mahananda. About 18 miles below the Bhagirathi entrance, the Bhairab spills southwards and joins the Jalangi. The united river flows south westward and meets the Bhagirathi at Nadia to form the Hooghly (Map at the end).

The three off shoots of the Ganga—the Bhagirathi, the Jalangi and the Mathabanga—form the system known as the Nadia Rivers. Nineteen miles below the confluence, the Mathabanga falls into the Hooghly at Chakdaha. The Port of Calcutta is situated on this River Hooghly. It is about 80 miles from the mouth of the river and 123 miles from the Sandheads—the open sea. About 30 miles below Calcutta, the Damodar falls into the Hooghly and another 4 miles further downstream, the Rupnarain, 24 miles below this, the River Haldia and 20 miles further down the Rasulpur flows in —being the last of the tributaries. The width of the river Hooghly off the Damodar is about 9000 ft. and 15000 ft. off Diamond Harbour. Below this, it is an estuary increasing to a width of about 15 miles off Saugor Island. Thus, we have reached the end of the river,—the end of a long 1680 miles course along which great changes take place till it spreads out through many different waterways and channels into the green fan of the Bengal Delta. (Map at the end. Index plan of Bhagirathi-Hooghly River System).

MOVING DOWN THE HOOGHLY FROM CALCUTTA

(i) The river Hooghly as a navigable channel is characterised, from the point of view of configuration by the devious course common to deltaic rivers. The map will give enough evidences of constant curvature, particularly up to Hospital Point near Diamond Harbour. As a navigable waterway the Hooghly does not enjoy the best of reputations. Treacherous shoals and sand banks, lurking but a few feet under the water's surface, swirling currents and sharp bends make the Hooghly one of the most dangerous navigable rivers in the world.

It has been mentioned earlier that the Port of Calcutta is situated on the left bank i.e., the eastern bank of the Hooghly, about 80 miles from the sea, but the pilotage water extends another 45 miles below Saugor. In this entire stretch, there are 15 bars viz , 1) Panchpara, 2) Sankrail, 3) Munikhali, 4) Pir Serang, 5) Poojali, 6) Moyapur, 7) Royapur, 8) Fulta, 9) Ninan, 10) Nurpur, 11) Eastern Gut, 12) Balari, 13) Jellingham, 14) Auckland, 15) Middleton.

In addition to these, following localities occasionally pose problems as the above 15 bars, but they are not of similar magnitude—a) Outram Shoal, b) Hastings Bar, c) Mutteabruz, d) Nazirgunj, e) Fisherman's Reach, f) Kukrahati Crossing.

(ii) While the estuary and the lower portion of the river between Saugor and Haldia, about 70 miles are fairly straight forward for navigation, the upper portion of 55 miles with 12 bars, is a complex stretch. In fact, about 1956, Balari Bar had very nearly caused a closure of the Port of Calcutta. Unusual shoaling took place on this Bar, fortunately an alternate channel i.e., Rangafalla saw us through these trying years. Luckily for the Port and by large for the country, realignment, hydraulic studies and tests with intensive dredging brought back the condition to normal in 1961 and then navigation through Balari Bar was reopened.

SEASONAL VARIATION AND ITS EFFECT

In order to find out the reasons for sudden shoaling of bars, it is necessary to understand the two distinct seasons which are experienced on the Hooghly.

(a) The dry season from November to about middle of July, when from about February, the flood current predominates over the ebb.

(b) The freshets or monsoons in knowledgable term i e. from mid July to end of October when the ebb current is predominant.

The changes in the seasons have a direct bearing on the depths at various crossings and in the channel alignments required to be maintained for navigational purposes. The transitory periods i.e. from dry to freshets and *viceversa* are the worse periods as then the river encounter sudden shoaling on navigational routes particularly on the upper reaches.

River Hooghly experiences the weakest current from mid November to beginning of February and during this spell, the effect of the disastrous 'Bore tide' is not much felt but then the vagaries of nature are their—the fog which impedes navigation sometimes. Also this season cuts down the movement of deep drafted vessels as the tidal heights are much less than in the other seasons.

(i) *Freshets*—Monsoon period is termed as freshets—this period lasts from mid July to end of October. The river gets an upland discharge which causes a good amount of flushing of the river bed. The sand entry from the feeder rivers moves down and initially causes sporadic shoaling in the Hooghly but as the ebb current is stronger than flood due to the discharge, it does not allow the sediments to settle down but instead scours and keeps the sands moving down seaward. In fine, it can be said that the general depth of the river attains best possible condition. Though governing depth over bars and crossings do not show appreciable improvement, high rise of tide gives the best pos ible draft for ships to negotiate the River Hooghly. Unfortunately, this good effect is short-lived and the good work done in this processes begins to reverse as soon as the freshets take off—then the rate of fall in the river level is very fast and this is met with in the flood season when upland redistribution of sand starts. The Hooghly during this dry season becomes tidal inlet. To minimise this upland redistribution, the idea of building the barrage at Farakka which would ensure regulated head water supply throughout the year was evoked.

(ii) *Bore Tide*—Increased tidal range in the upper part of the Hooghly and decrease of depths in the River are the main reasons of much talked about term "The Bore Tide". In simple term it can be said that sudden rush of water taking the shape of a huge wall moving upstream with terrific power behind it in the upper reaches of Hooghly first noticeable from about 26 miles downstream of Calcutta—this occurs at the instance of low water during perigee spring tides. The impact of this massive wall of water is so great that it causes great amount of damages to life, properties on either banks of river, ships tied up to buoys in Calcutta moorings. Particularly in the last couple of decades, the position in respect of bore tide has aggravated. In 1947, we had only 70 bore days. In 1962—it was 161 days (fig. 4). Now the strength of bore tide has reached an alarming proportion that even ships drawing less than 18 ft. draft cannot be kept in the river moorings —what a contrast—in late thirties, ships of 26 ft. drafts were kept in river moorings during bore tides. The Port has capacity of keeping more than 60 per cent of ships in moorings but the devastating 'bore' does not permit even 15 per cent use of these moorings. Consequently, the two docks either gets

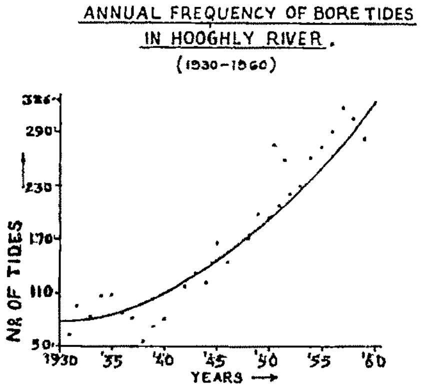


Fig. 4

congested or the ships are made to wait outside at Sandheads—this adversely affects the port's earning capacity.

During the bore tide period, the following restrictions are normally imposed in the port—

Calcutta—Max. length—500 ft. draft 18 ft.
Buj Buj— „ 525 ft. draft 20 ft.

(iii) *Deterioration in depths*

Progressive deterioration in river depths which in turn had affected the draft of ships in the port. The following statement showing the number of days vessels of 26 ft. draft could not use the port.

1938	—	74 days	1958	—	355 days	1965	—	335 days
1942	—	228 days	1961	—	365 days	1966	—	282 days
1946	—	270 days	1962	—	352 days	1967	—	354 days
1950	—	302 days	1963	—	309 days	1968	—	345 days
1954	—	217 days	1964	—	330 days	1969	—	350 days

From the above statement one should be able to easily visualise the complexity of the problems and the formidable task which challenges the existence of this port particularly under the present day context.

(iv) *Fluctuation in depths and its maintenance*

There are hardly any other port in the world where the depth fluctuation are as alarming as in the River Hooghly. As a result of which large scale surveying and dredging organisations have been set up to maintain the channel depths and also to give up-to-date depth position to the ships calling at the Port. Surveys are carried out to a high degree of accuracy at various crossings at regular interval and at times even twice a day. Crossings are sounded and depths are broadcast over W/T daily to facilitate the ships in negotiating them. Over 1000 charts are printed annually in expedious manner and circulated amongst Pilots for their benefit. In addition to this, numerous types of bed surveys are carried out for study purpose and planning improvements.

At important crossings, the tidal information is exhibited by what is known as 'Semaphores'. These indicates nearest to three inches of tide. The rise and fall of tide plus the latest depths on various bars and crossings gives invaluable help to the Pilots navigating ships in the Hooghly.

The dredging in the Hooghly had started since 1907 but as time went on the dredging effort increased progressively. The dredging requires careful planning and for it to be effective it must be done to assist the natural forces of the river. Port of Calcutta have a large number of dredgers with modern fittings. In 1947-48 the dredging quantity was about 7 million tons and 1967-68 it was of the order of 21 million tons with a corresponding rise in cost, of dredging from Rs. 73.73 lakhs to Rs. 735.25 lakhs (fig. 5).

(v) *Pilotage*—The hazards of piloting

ships in the Hooghly are well known. The various conditions enumerated before call for a skilful pilotage. The ships are piloted under almost all weather conditions day and night There are also limitations on the number of outgoing deep drafted vessels due to the limited space available in the stream before moving down. Deep drafted vessels take about 36 38 hours to proceed out to sea whereas the light ones take about 14 hours working at 10 knot speed. Inward bound vessels take about 10 hours to reach Calcutta from sea. The Port authorities engage different set of pilots to navigate the ships within the Port area. This harbour pilotage though only a few miles in length is equally hazardous on account of restricted space for manoeuvring. In fact, due to this restriction, vessels have to back down right from Howrah Bridge to Garden Reach all the time heading the ebb current which gives better control on the vessel movements—this is a difficult task.

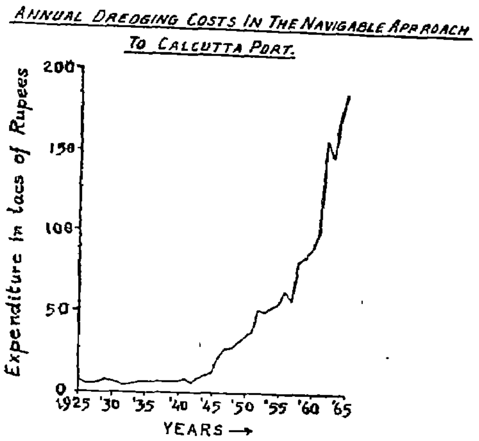


Fig. 5

Another set of pilots are employed to navigate within the two docks. It has its own peculiarities also—movement within very limited space without the help of any current. Tugs are employed for such movements. Quite frequently, these pilots have to navigate without the ships engine.

(vii) *Despatch vessels*—These are a type of vessels which renders assistance to stranded vessels They also look after the maintenance of over 120 channel buoys of which 82 are lighted, 500 river marks including 140 lighted marks required for the safe navigation in the river. These also look after the manned and unmanned light vessels in the estuary.

(vii) *Wireless Stations*—The port of Calcutta has its own wireless stations essentially meant for navigation. Round the clock services are rendered by such stations.

CONCLUSION

In other parts of the world overwhelming revolution, meaning container revolution, container era, container boom are changing the pattern of shipping operation. Even a maritime nation like Britain which has been in the forefront of shipping for over a century, is meeting stiff competition. Let this not cast a gloomy veil. In spite of the navigation and maintenance of the River Hooghly which is a constant struggle of man against nature, hazards and problems of navigation will always remain due to the geographical reasons, but if the application of modern equipment, various schemes and projects are successful together with probably the most experienced dredging service, river survey and marine officers in the world and with the guidance of the Hydraulic Study Department, the Port will have adequate depths in the near future when it would be possible for 26 ft. drafted vessels to navigate up to Calcutta almost all days of the year, whereas 28 ft. drafted vessels would be able to come 200 days and 29 ft. for about 100 days in a year. In addition to this, the work at the subsidiary deep water port at Haldia, is well in progress. Once this project work is ready, this port will be able to cater for much deeper drafted and bigger vessels carrying cargoes in bulk. It will open a new horizon in the chapters of Indian shipping tonnage keeping pace with the other modern ports in the world.

REFERENCES

Bhaskaran, T. E. & Shanmugam, A. T. (1968) : *Sand drift on the Eastern coast of India and its impact on Major ports*—presented at 1st National conference on Port & Harbour Management—Calcutta, pp 16.

Calcutta Port Commissioners. *Technical Data* compiled by Hydraulic Study Department.

Duke, C. M. (1961) : *Shoaling of the Lower Hudson River,* Proc. of A.S.C.E. (waterways & Harbour Div.) Vol. 87 pp 65.

Indian Meteorological Department (1964) : *Tracks of storms and Depressions in the Bay of Bengal and the Arabian Sea 1877-1960.*

Langbein, W. B. (1962) : *Hydraulics of River Channels as related to navigability,* U.S. Geological Survey, water-supply paper 1539-W. pp 30.

Leopold, L. B., and Maddock, Thomas, Jr. (1953) : *The hydraulic geometry of stream channels and some physiographic implications,* U.S. Geol. Survey Professional Paper 252.

Minikin, R. R. (1963) : *Winds. Waves and Maritime structures chapter* 8. p 294.

Mukherjee, N. (1968) : *The Port of Calcutta—A short history.* pp 276.

Termier, Henri & Termier, Genevieve (1963) : *Erosion and Sedimentation* Ed. Fairbridge, D. Van Nostrand Company Ltd., London, pp. 433.

NAVIGATIONAL PROBLEMS AND HAZARDS IN THE PORT OF CALCUTTA

R. E. MISTRY

Abstract

The navigational problems of the River Hooghly can be appreciated when we compare a riverine port to a sea port.

A sea port has to cope with the problems of wind, wave and swell but the problems of bars, bores and bends in the River Hooghly are far more complex.

The comparatively straight and wide channels of the lower reaches do not pose many problems to a ship coming up to Haldia but the narrow upper reaches above Diamond Harbour create many problems for the ship's movements to and from Calcutta. They are—*Bars* : 12 bars or shoals to be negotiated. *Bends* : Narrow and winding channels restrict length and speed of ships. *Bores* : Low-powered ships restricted from arriving or leaving Calcutta. Unable to keep ships in river moorings during bores. *Tide* : Tidal occurrence at different times along the river. *Fog* : Danger of grounding and collisions. *Freshets* : Strong currents and eddies make dragging of anchor and sheering hazardous. *Neaping* : A ship missing a single high tide may be delayed for a week—inward or outward. *Nor'westers* : Strong winds in local storms make anchoring in narrow channels difficult. *Night Navigation* : Restrictions and hazards. *Anchorages* : Limited safe anchorages. *Towing* : Disabled ships with tugs. *Impounded Dock System* : Filling and emptying of locks delay ship movements. *Groundings* : Sand-scouring effect on grounded ship disastrous.

The main function of a port is to facilitate the passage of goods and passengers between ship and shore. But a port must also give shelter against wind, wave and swell. A seaport's major problem is to create this shelter (or harbour). A port like Calcutta gives natural shelter from wave and swell, but a river port 120 miles up the river Hooghly creates many more problems of bars, bores and bends.

Ports must maintain sufficient depths of water for deep ships to remain afloat while loading or discharging cargo. In an impounded dock the water is kept stagnant at a constant level. But the sea level, and more so the river level, is subject to the rise and fall of the tide.

The port has a choice of bringing the deep ship at high tide and quickly putting it into the impounded dock where the ship will not be effected by the falling tide, or, berth the ship in tidal waters where the depth is sufficient to keep it afloat even at the lowest tide.

On the sea coast the range of tide i.e. the difference of water level between high water and low water, is small. Consequently the tidal current (i.e. the flow of water) is weak. But as we proceed further inland, up a river or an estuary, the range and current of the tide increase—culminating into the heavy bores we see in the river at Garden Reach.

Sea ports like Madras, Visakhapatnam or Cochin, because of their weak tidal effects, do not need to have an impounded dock system. In Calcutta, due to the strong effect of the tidal bores, both on the ship and the river bed, ships have to be impounded in the wet docks. It is also cheaper to construct a wet dock for a given range of tide than to go digging up a tidal basin of equal size.

The river moorings in Calcutta also harbour ships from wind, waves and swell. They can serve as waiting berths. Cargo can also be worked overside in the moorings. But just as in a seaport, during a storm, a ship has to either get into the shelter of a dock or put out to sea ; in the river, during bore tides, ships have to either get into the docks or get out to Diamond Harbour or Haldia where bores don't occur.

From the navigational point of view a seaport has the problems of wind, sea and swell which make shiphandling a hazardous business near the entrance to the port. But the piloting is only for a five-mile stretch or less. A riverine port has many more miles of pilotage.

To appreciate the navigational hazards of a river, an elementary knowledge of shiphandling will be very helpful.

A ship is a means of transport like a goods van or a railway engine. But the similarity ends there. Whereas a land vehicle can run on the road or on fixed railway tracks, a ship is subject to the elements of wind, wave, tide etc. At most a ship can be compared to an enormous van running on a slippery road with only a very poor front brake available as an anchor.

Now imagine such a vehicle running on a road barely wider than the length of the vehicle itself. A van struggling up a slope would be akin to a ship coming up the river against the tide. If the van wished to stop in the middle of the road all that the driver has to do is to slow down and jam the brakes (front brakes only). Similarly a ship heading into the tide would slow down and drop its anchor and remain hooked on to it. But being mobile a ship could stray all over the channel while slowing down.

But a ship coming down the river with the current flowing in the same direction as the ship's movement would be like the van hurtling down the slippery slope. If the driver now wished to stop his vehicle by jamming his front brakes the van would surely skid off the road. Similarly a ship coming down with the current and wishing to anchor must have enough room to swing its entire length on the anchor and allow for the drift or skid while doing so. Otherwise the vessel can stray outside the navigable channel and ground.

BARS

Bars are shoals or underwater hillocks that stretch like barriers across the river. Since a ship cannot ride over these risings, the tide must raise the water level to allow the ship to cross them. Usually a port has a single bar at its entrance but Calcutta has to cope with over 15 bars in the river. Usually the sea bars remain constant throughout the year but the river bars undergo daily and seasonal changes. A bar near Hooghly point opens to 20 feet in September but can shoal to 5 feet in March. A river bar can shoal suddenly by three feet in a single tide.

BENDS

In a winding river the tide scours the sand in the bights or curves and deposits it on the crossings. These bends are so sharp that big long ships are unable to round them. The bends restrict the length of ships coming to Calcutta.

BORES

The mouth of the river Hooghly is wide. But as we proceed up the river, the river gets progressively narrow. During full moon and new moon the tides are high and strong. In the lower part of the river, only a strong flow is experienced. But when the same volume of water has to get through a restricted channel, a sort of bottle-neck is created and the water piles up in the form of a wave, causing a bore. As bores only occur during the change of tide from ebb to flood, swinging a deep ship on its anchor forms the most hazardous part of a pilot's job.

The tidal current during bore tides is very strong. Consequently slow ships are restricted from going up or down the river. The ships in the moorings also have to be taken into the safety of the wet docks.

TIDE

The tidal occurrence takes place one hour later every 20 miles up the river. This means that if high water or a certain state of tide takes place at a certain place at say eight o'clock, the high water or the same state of tide 20 miles up river will be one hour later —at nine o'clock. Therefore, when coming up the river, ships which normally can do a speed of 10 or 12 knots will always lag behind the tidal phenomenon which is travelling up at 20 knots. Ships, in order to arrive at Garden Reach at high water must, therefore, start before high water to catch up with the tide.

This is not much of a problem with an incoming ship. But the outward bound ship has to battle against an incoming tide. Besides. the ship going out is all the time getting to a place where the tidal occurrence has preceded it. This creates many problems for a deep ship.

FOG

Along the Indian coast fog is peculiar to Calcutta only. To anchor a vessel in a restricted channel under ordinary circumstances with the current flowing the same way as the ship's headway is difficult by itself. In a fog it becomes extra dangerous due to the chances of collision or grounding.

FRESHETS

After the monsoons the upland waters pour into the river Hooghly, increasing its outward flow. The ebb tides rush out at seven knots. Handling low-powered ships in such tides is as hazardous as in the bore tides.

NEAPING

In spring tide the tides keeps rising higher every day till at its highest towards full moon or new moon. Deeper ships can come up or go down the river at each successive tide. If a vessel meant to cross a bar at the highest high water happens to miss the tide she cannot cross the bar till the tide rises again to the same level at the next spring tide which may be a week or two latter. This is called neaping, i.e. the ship is jammed in during the neap tides.

NOR'WESTERS

These are the local storms that blow from the Northwest very violently during March and April. Other ports also have their local storms of small duration but with the room available they do not pose the same problems as in the congested channels of the river Hooghly.

CYCLONES

Monsoons and cyclones are a source of anxiety to the river pilot. The pilot has to embark and disembark in the open sea at Sandheads. In the heavy sea and swell during the monsoons, climbing a rope ladder dangling from the ship's side forms the most hazardous part of a pilot's life.

A vessel caught in the river during the storm has to weather it at anchor with the danger of the anchor not holding in the ground and the vessel consequently grounding or colliding.

NIGHT NAVIGATION

A deep-drafted ship outward bound can cross the various bars on the flood tide only. As mentioned earlier a ship going out against the incoming tide is getting to a place where the tidal occurrence has already preceded it. Thus, the vessel can use the flood tide for a limited period only. To solve this problem deep ships have to use the night flood tide to negotiate the first 15 miles from Calcutta to Ulubaria or Royapur anchorage. The deep ships have to get to these anchorages before the tidal current changes from flooding to ebbing so that the deep ship may not have to hazard a 180 degree turn at night in the restricted channel. The ship remains at anchor for the entire period of the ebb tide and negotiates the next 15 miles to Hooghly point on the following flood tide. Below Hooghly point the river is sufficiently wide to allow night navigation on the flood or ebb.

Night navigation involves the risk of swinging a ship at anchor to the night bore and negotiating sharp bends in very strong currents. No ships are allowed to come up at night because this would entail navigating with the inward current and meeting ships at night which can in no way be safe.

ANCHORAGES

Although the river has many deep bights or pockets where deep ships can anchor and remain afloat even at low water, the tidal eddies and cross-currents allow only three anchorages in the upper part of the river to be used with comparative safety. This limits the number of ships that can sail out at night.

TOWING

Ships like motor-cars can suffer from engine breakdowns. A slow ship is a problem by itself Towing a hampered ship with tugs is a delicate operation in the river.

SHIP MOVEMENTS

There is a limit to the number of ships allowed in or out of the port. Deep ships can only leave during the spring tides and that too is limited to four or five sailings a night depending upon the anchorages available and the condition of Garden Reach anchorage.

During heavy bores all the ships in the river moorings have to be taken into the safety of the wet docks. This causes congestion in the docks. Deep ships are taken into the docks after high water. Only one ship can be taken into the dock at a time. The time taken in filling and emptying the lock can also limit the number of deep ships that can be accommodated every day.

It is ironical that during the bores when ships can take advantage of the high rise of tide they are restricted from coming to Budge Budge or the river moorings.

GROUNDING

Grounding in the river can be far more serious than in other ports where assistance can be available at short notice. In a port like Cochin where the rise and fall of the tide is barely three feet the damage to a ship grounded at high water will be little. But in the river where the water level can fall 16 ft the stresses and strains on the exposed hull are colossal. The tidal stream scours the sand from the bottom of the ship creating uneven strains on the hull. The hull of a ship is, proportionally, more vulnerable than an egg-shell.

It takes hours for any tug to come to the assistance of a stranded ship down river because the tug has to unmoor and leave from Garden Reach. If the tide is not favourable the tug may be delayed further in reaching the vessel in distress. And all the damage can be done in a single falling tide.

HALDIA PORT

The river Hooghly serves as an inland waterway for Calcutta Port with its vast hinterland and population. This makes Calcutta an important port even with all the restrictions imposed on its navigation.

But the dimensions of nearly all ships is on the increase and a port must cater to this trend. Even if the depths in the river improve after the completion of the Farakka Barrage, the sharp bends in the river will restrict the length of ships coming up to Calcutta.

Haldia—70 miles downriver—is not beset by the problems of bores and bends. There are only three long bars along the straight and wide channels of the lower reaches below Haldia, whereas no less than 12 bars exist from Haldia to Calcutta. The lower bars are deeper and they do not undergo such drastic changes in their depths as do the bars of the upper reaches. Therefore, larger and deeper ships will be able to come up to Haldia.

Haldia can also serve the needs of an oil refinery which is usually situated close to tidal approaches but a little isolated from the main port installations.

The river Hooghly is the life stream of Calcutta and its vast hinterland. As long as water flows under the Rabindra Setu, the river will continue to serve Calcutta and its millions.

HISTORY, DEVELOPMENT AND PROBLEMS OF DREDGING IN THE RIVER HOOGHLY

H. P. GHOSH

Abstract

The question of improving the navigable depths of the upper reaches of the Hooghly arose with increasingly larger vessels entering the Port of Calcutta. The 19th century dredging machines could not effect any appreciable improvement. Regular dredging of the navigation channel started in 1907. Shoaling of the upper bars was evident by mid twenties. Early attempts in dredging resulted in local improvement on major bars. Depths continued to deteriorate due to diminution of head water supply. By 1967 a large fleet of 7 dredgers were engaged in a vain attempt to arrest the falling depths. The completion of the necessary corrective works and restoration of head water supply will reduce the dredging commitment and improve the navigability of the river to that existed in 1936-38. The depth in the approach channel to Haldia can be deepened to 28/30 ft. to cater to 40 ft. draft ships for 209 days in the year.

The difficulties in the approach channels to the Port of Calcutta were recognised from the ancient days of sailing ships. In the earliest days, the larger sailing vessels loaded and discharged their cargo into smaller river boats in the deeper and wider lower reaches of the river below Diamond Harbour. Only the smaller vessels ventured to make the difficult passage through the tortuous upper reaches of the Hooghly. The wooden sailing ships of the 17th century under 100 feet in length and 18 feet loaded draft, of different nationals, started plying where their own trading forts were established as far up the river as Chandernagar and Hooghly. The Port of Calcutta began to develop around the Fort William, which was established in 1696, and vessels were brought up and anchored off Princeps Ghat.

The steam tugs appeared on the Hooghly around 1827 and their advent marked the beginning of a new era of navigation in the Hooghly. The highest conception of seamanship as exemplified in conducting a sailing ship through the intricate and dangerous channels of the upper reaches was to undergo a radical change with the acceptance of power towage of sailing vessels in the Hooghly. The arrival of the steam tugs, improvement of the surveys of the river and the demands of the trade all led to increasingly larger vessels making the passage to Calcutta.

Steam vessels began to make their regular appearance in the Hooghly during the last two decades of the 19th century. The sizes of ships plying from the European countries were dependent on the navigational limitations of the Suez Canal. With the rapid increase in the size of vessels entering the Hooghly, the question of improving the depths of the channels immediately arose.

THE EARLY DREDGING

The earliest record of dredging on the Hooghly that has been possible to discover refers to the East India Company's dredging Barge "Pluto" which apparently operated in 1820. An eight horse power steam engine brought from Birmingham in 1817 or 1818 did nothing but gather dust in a Calcutta warehouse until purchased by the Company's Government for use on a dredger. This steam engine, one of the first afloat in Bengal, 'hitched to a double set of revolving buckets mounted on a barge' performed the humble duty of 'scooping mud' from the river bottom to clear the passage for Calcutta bound conventional sailing vessels. Presumably the "Pluto" was not very successful in deepening the Hooghly or perhaps the need of its operations was not greatly felt, for in 1825 the Government assigned a naval mission for the dredger. With a false bow hung over one of her square ends and paddles in place of buckets, this early dredger accompanied a flotilla of frigates to be used in the Burmese war for operation on the Arakan Coast.

For over forty years after the "Pluto" episode no attempt of any kind was made to dredge the Hooghly. In 1854 a suggestion was made for stirring up the sand on the shallow crossings, but it was not until 1863 that such an experiment was made. In that year attempts were made to rake the Eastern Gut and the Dredge Channels, but the steamer "Sitang" employed to drag the apparatus along the bottom was of only 60 h.p. and could make little headway against the strong tide. The trials were entirely experimental and the operations were discontinued when the sum granted by the Government for this purpose was expended. Although the machine used had several faults the results of the experiment must have been encouraging as it was recommended to build a powerful tug and improved raking apparatus for the purpose.

The steam tug "Agitator", 132 feet in length and of nearly 400 tons burden with a 200 h.p. engine was then specially built 'to drag one to three rakes over the bars at a fair rate against a four knot current'. This vessel was first employed on the Eastern Gut Bar during May, June and July of 1867. Fitted with 'Splendid harrowing gear' the dredger was tried on Eastern Gut and Moyapur Bars from 1867 to 1869 but effected no appreciable improvement.

As a result of the failure of the "Agitator", the experts were apparently convinced that the action of the most powerful dredger would be ineffective on any of the Hooghly shoals. This view was possibly correct with the dredgers of the period. In 1870 the

Port Trust was formed which gave the management control of the Port of Calcutta to the appointed Commissioners. The survey and maintenance of the river, conservancy of the Port and berthing of vessels all came within the jurisdiction of the Commissioners.

During the next twenty seven years the old idea of stirring the shoals was revived from time to time until it was finally discarded in 1897 in favour of a proposal of fitting a small sand pump on the despatch vessel "Resolute". This proposal apparently did not take shape as the authorities admitted their inability to dredge the Nimtolla Shoal in February, 1899 for want of a suitable dredger.

However, with the turn of the century hydraulic suction dredgers had sufficiently developed to carry out an experimental dredging with a cutter suction dredger "Lindon Bates"—named after an American engineer. The "Lindon Bates", a 400 h.p. dredger fitted with cutter and 18″ diameter suction and delivery pipes, dredged at Royapur and also reclaimed a portion of the right bank of the river in the port area off Ramkristopore. At the end of April, 1902 this dredger was taken up the Bhagirathi, having dredged through the Gayespur Bar on the Upper Hooghly near Kanchrapara. In April 1905, the "Lindon Bates" dredged and cleared away the Nimtola Shoal which had reappeared in March the same year.

DETERIORATION OF DEPTHS AND DEVELOPMENT OF DREDGING

The experiment with the "Lindon Bates" led to further consideration of the possibility of the dredging the bars of the Hooghly. On February 22nd 1907 the suction dredger "Sandpiper" built at a cost of Rs. 11.14 lakhs arrived from England to start the first regular dredging of the approach channels to the Port of Calcutta.

The "Sandpiper" was a push type plain suction dredger with two side suction pipes fitted with shoe heads and dredged by moving ahead on her own anchor cables while discharging the spoil, at 5000 tons per hour, through a floating pipe line, attached to the stern of the vessel. The floating pipe lines, 600 feet to 1000 feet long, became almost unmanageable in the strong tides and a serious breakdown led to the attempt to work without the pipe lines and to discharge the spoil on the surface of the water astern of the ship. This dredger was in fact a pure agitation dredger having no provision of any kind for the collection of the dredged spoil but merely by placing it in suspension in the river and relying on the strong currents to carry it clear of the shoal area. This dredger was primarily intended to work on the Eastern Gut Bar and in 1911 it was estimated that the "Sandpiper" had increased the navigable depth of this critical bar by 3 feet. The "Sandpiper" also contributed materially in opening the new Gabtola route in 1912. This encouraged the Commissioners to order another dredger.

The new dredger 'Balari' which arrived in Calcutta in 1913 was still a plain push suction dredger working on her anchors. The dredger was, however, designed to load the dredged material in a hopper of 3000 tons capacity and a single suction tube was now fitted inside the hull in a bow well. The spoil was freely dumped into selected disposal areas of the river through bottom discharge valves. This dredger was employed mostly on Moyapur and Royapur Bars. By 1919 improved results to be obtained from long dredging cuts had been fully established and the new dredger was equipped with a draghead and arranged to dredge underway going astern using the strong currents of the Hooghly. This adaptation proved successful. Results superior to the "Sandpiper" were reported and it was decided to add another suction dredger to the fleet.

The development of design of the new dredger was limited by the belief that a dredger could not work underway against the tides of the Hooghly. However, the proposed dredger was taken over by the Admiralty, at the builder's yard, and never reached Calcutta. Immediately after cessation of the First World War the proposal was revived and it was decided to build the dredger with a hopper capacity of 4000 tons.

This new dredger "Ganga" was commissioned in 1921 and was fitted with reversible suction tube with a "Fruehling" type draghead in the bow well, so that she could work underway, either with or against the tide. Experience soon showed that dredging on the Hooghly when underway against the tide was both practical and advantageous.

In 1920, ships of 550 feet in length were plying on the Hooghly with drafts upto 32 feet. This draft was available as the depths on the upper bars were sufficient. However, by mid-twenties, gradual shoaling of the upper bars was evident and the number of sailings of deep drafted ships were affected. So long as depths on the Upper Bars were 22 feet and more, deep drafted ships crossed the upper bars on the ebb tide and met the flood at Moyapur Bar 15 miles below Garden Reach. But as these depths began to deteriorate the sailing of deep drafted vessels became a problem. To overcome these difficulties of deep draft sailings the river from Garden Reach to Ulubaria was opened for Night Navigation in the year 1929 and the ships crossed the upper bars on the night flood tide and anchored at the Ulubaria anchorage.

The operations of the three dredgers, "Sandpiper", "Balari" and "Ganga" were so successful that by 1938 there was sufficient depths over the bars to allow 24 feet draft ships to sail at 'Tide time' and ships upto 30 ft. in draft to both enter and leave the port during spring tides using the anchorage at Ulubaria. The initial success in improving the depths with the three dredgers which was the result of purely local improvement of depths on major bars, tended temporarily to obscure the progressive loss in capacity of the upper reaches of the river caused by the diminution of the vital head water supply. In fact the limit of improvement of depths to be obtained by dredging alone had probably reached by 1938 as the depths available during that period were never again to be seen.

In 1938 it was decided to prepare plans for a new dredger but the war again put a stop to the development of these plans. At the end of the Second World War order was placed for an oil fired 3000 tons hopper capacity bow well suction dredger. In 1950, the "Sandpiper" which was no longer serviceable was replaced by this new dredger "Jalengi". Inevitably the depths continued to deteriorate and in 1958 the dredger "Bhagirathi" a sister ship of the "Jalengi" was commissioned.

In the meanwhile a scheme for the improvement of James and Mary Reach was undertaken which consisted of recession of the Fulta Point. This dredging was entrusted to a firm of contractor M/s. N. V. Amsterdamsche Ballast Maatschapping who engaged their cutter suction dredger "Lake Fithian" in 1958. In 1960 a second cutter suction dredger "Queen of Holland" was brought to assist the "Lake Fithian". Unfortunately, on Saturday the 19th November, 1960, the "Lake Fithian" unk in the river while in operation off the Fulta Point. Eighteen members of a total of fifty crew were trapped inside the vessel and were drowned. The "Queen of Holland" completed the job by the end of 1961 and in early 1962 she supplemented the efforts of the Commissioners' dredgers in opening a new alignment on the Balari Bar.

In 1960 a second hand dredger the "Maitena" was purchased and in 1961 another new dredger the "Churni" was commissioned. The "Churni" was basically similar in design to the "Bhagirathi" but was provided with extra crew accommodation for round-the-clock operations.

Dredging being only a palliative inasmuch as it did not attack the root cause of the trouble, the depths continued to deteriorate progressively. In 1967 with the addition of another new dredger the "Subarnarekha" a fleet of 7 large suction hopper dredgers were engaged incessantly in a vain attempt to arrest the falling depths.

A similar position prevailed in the port area where dredging for the maintenance of depth in the docks, locks, lock entrances, river moorings and jetties was first started in 1894 with the bucket dredger "Bruiser". The resultant increase in the intensity and incidence of bore tides due to the progressive deterioration of the upper reaches has resulted in such severe shoaling that even the enlarged port dredging fleet which in 1967 consisted of three bucket dredgers, two grab dredgers and two small suction hopper dredgers was unable to cope.

By then it had been established that dredging alone was incapable of resorting the position but had to be accepted as an inevitable evil until the necessary corrective river training works were both designed and constructed and the head water supply restored by the implementation of the Farakka Barrage.

ESTUARY DREDGING

The development of the deep water dock system at Haldia, situated 25 nautical miles upstream of Saugor in the River Hooghly brought in its wake the necessity of deepening the approach channel from sea to the dock site.

The main impediments to unhindered passage of the new generation of deep drafted vessels through the 39 nautical mile channel from deep waters to Haldia are the existence of two shoal patches. The first one in the inner estuary Jellingham / Auckland shoal is at a distance of 6 to 10 nautical miles and the second one in the outer estuary —Middleton/Gasper channel at 28-36 nautical miles from Haldia. The tidal rise, configuration of the bank, set of wind and the due clearance necessary under the keel, make it possible, with some restrictions, to maintain the channel depth of the inner estuary 2 ft. less than that of the outer estuary. Examination of all aspects of the estuary, the expert opinions that have been received and experimental dredging carried out in the estuary, confirm that a channel can be developed to a depth of 28/30 feet in the first instance. The possibility of developing and deepening the channel further to 30/32 feet and also to 34/36 feet exists.

It has been assessed that for the development of a 28/30 feet channel varying in width from 1000 ft.—2000 ft. which will provide access to 40 ft. draft ships for 209 days in the year, 57 million tons of *in situ* material is required to be dredged.

To execute the task of deepening the approach channels to Haldia the Commissioners acquired in 1965 a trailing suction hopper dredger, the tool which has been playing such a major role in providing deeper lanes of access to sea ports all over the world. This new dredger "Mohana" built in Holland at a cost of Rs. 4.28 crores is designed for all the year round work in the exposed estuarine approach channels. With a length of 405 feet, loaded draft of 21 feet and a hopper capacity of 5000 tons the "Mohana" is not only the largest dredger owned by the Commissioners, it is the largest in India. The twin suction tubes of 36 inches diameter are fitted with flexible joint at each section and a swell compensator to permit dredging to be carried out in heavy weather in swells upto 10 ft. The dredger has a free cruising speed of 12 knots, in loaded condition, and a trailing speed varying from 2 to 6 knots, and can dredge upto a maximum depth of 55 feet. Besides the normal navigation equipment such as radar, gyro compass and echo sounders the dredger is provided with much that is special to a dredger like the automatic load and draft indicators, Decca Hi-Fix equipment with associated track plotter, depth and angle indicators showing the precise orientation of the suction tubes and drag heads.

After the initial period of "working up" the "Mohana" started dredging from the seaward end of the designed approach channel from December 1968. An output of 10 million tons was achieved in the first year but the dredging of the approach channel had to be interrupted from time to time due to more urgent requirement of maintenance dredging in the inner estuary for the access of large tankers to the Haldia Oil Jetty which had already started functioning. It has been estimated that after meeting the requirements of maintenance dredging the "Mohana" will have little capacity left to deepen the channel beyond 24/26 feet. A 24/26 feet channel can provide access only to

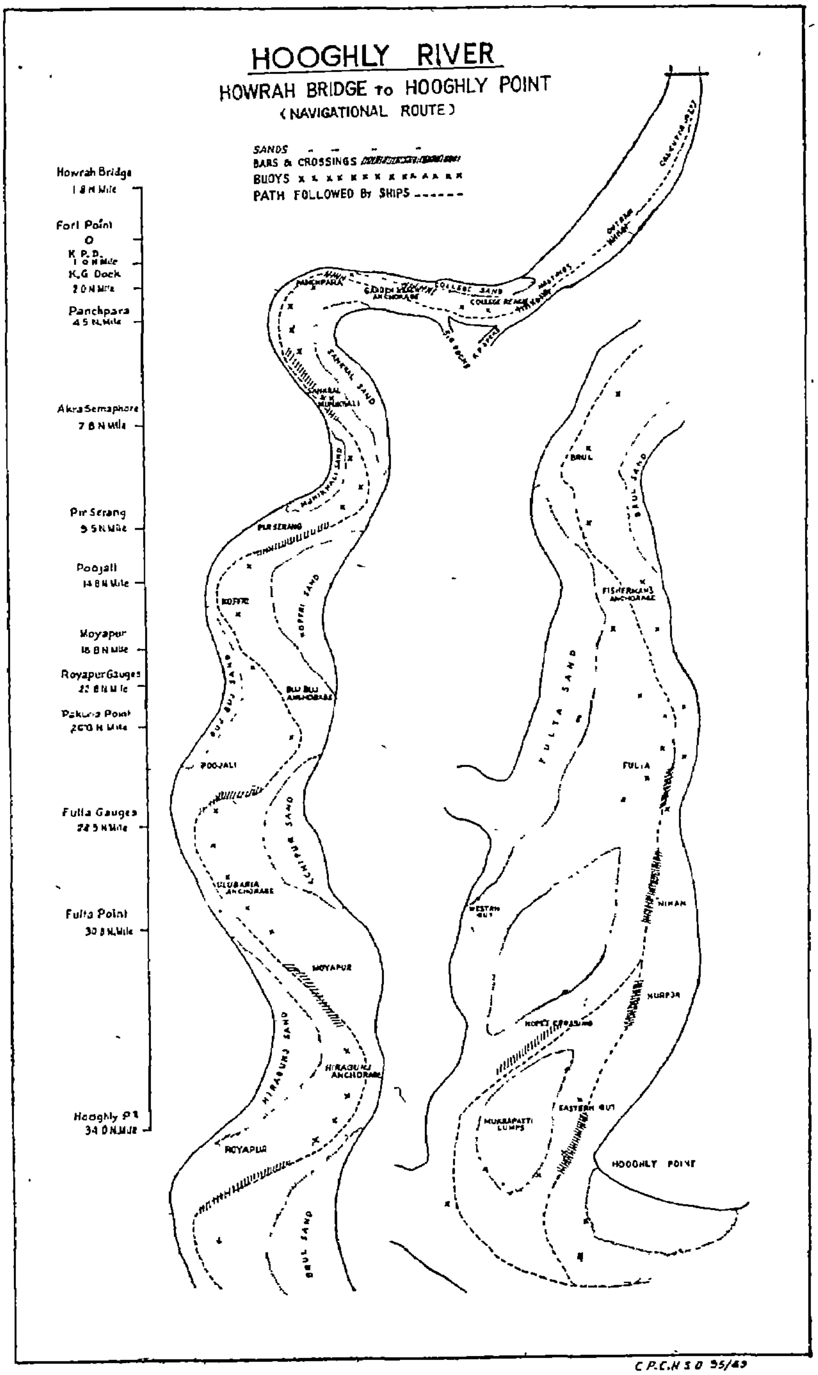


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Fig 1

36 ft. draft vessels for 209 days in the year. The size of tankers and bulk carriers plying in important trade routes for which the Haldia Dock is being built requires a draft of 40 ft. to be provided. Considering these factors and for early completion of the project the Commissioners have decided to acquire another trailing suction dredger of 8400 tons hopper capacity.

PROBLEMS OF DREDGING

The passage of sea going ships from the Pilotage station at Sandheads to the Docks through the 123 nautical mile long channels of the Hooghly is hindered by the existence of several bars and crossings. The position of safe anchorages available for ships at all states of tide, conveniently divide the entire navigation route into three sections. In the first 34 nautical mile stretch of the river from Calcutta there are 14 bars and crossings, (Fig. 1). Thus :

Bars/Crossing.	Distance in nautical mile from Fort Point.	Bars/Crossing.	Distance in nautical mile from Fort Point.
1. Outram	0.0	8. Poojali	15.0
2. Hastings	1.0	9. Moyapur	18.8
3. Nazirganj	3.5	10. Royapur	22.8
4. Panchpara	4.5	11. Fulta	30.8
5. Sankrail	7.0	12. Ninan	31.0
6. Munikhali	7.5	13. Nurpur	32.0
7. Pir Serang	9.5	14 Eastern Gut	34.0

The principal anchorages in this stretch of the river are at Garden Reach and Ulubaria at 4.5 and 16.0 nautical miles respectively from Calcutta.

In the next 44 nautical mile stretch downstream of Hooghly Point there are three shoals viz., Balari Bar, Jellingham and Auckland shoals, with anchorages at Diamond Harbour/Kalpi at the upper end and Saugor at the lower end (Fig. 2). On the last stretch from Saugor Roads to the 'Pilotage Station' at 'Sandheads' two shoals at Middleton and Gasper exist. The location of these bars and crossings and the depth of water available over the shoals determine the state of tide at which a vessel of any draft or speed must navigate the river.

The dredging problem lies in providing sufficient depth over the bars for safe navigation between the anchorages. The maximum draft of the vessels trading at present to the Port of Calcutta, excluding tankers, ranges between 26 ft. and 30 ft. The ideal depth requirement on the upper bars, for these vessels to proceed up and down at maximum draft without restrictions are 18 ft. to 21 ft. and 21 ft. to 24 ft. during spring and neap tides respectively. The depth required to allow navigation of a 26 ft. draft ship on any day is evaluated at 18′-6″ on Moyapur and less for remaining bars and crossings upto 16′-6″ at Hooghly Point area. Due to the progressive deterioration of depths during the last few decades these requirements were never fully met. In 1938,

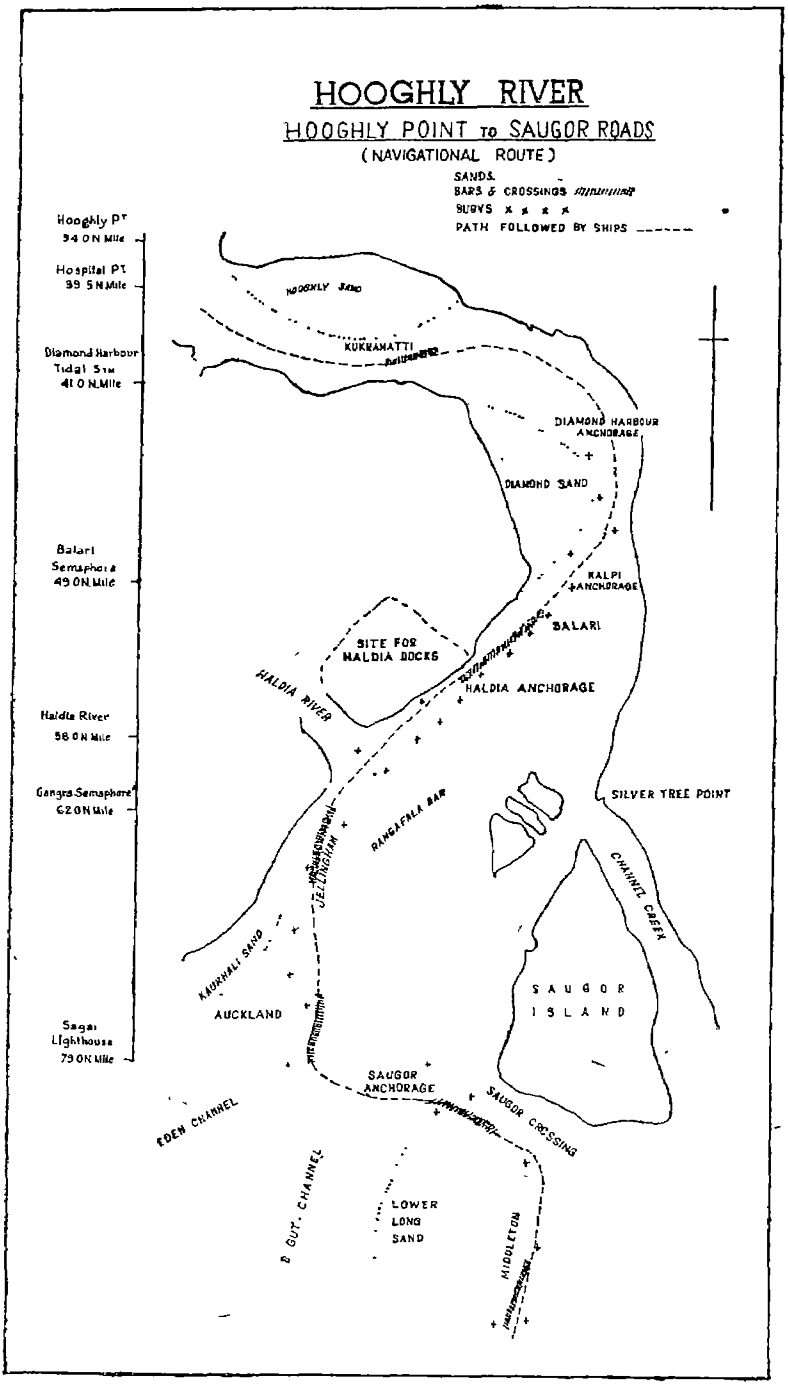

HOOGHLY RIVER
HOOGHLY POINT TO SAUGOR ROADS
(NAVIGATIONAL ROUTE)
SANDS
BARS & CROSSINGS
BUOYS × × × ×
PATH FOLLOWED BY SHIPS
Hooghly Pt 34 0 N Mile
Hospital Pt 39 5 N Mile
Diamond Harbour Tidal Stn 41 0 N Mile
Balari Semaphore 49 0 N Mile
Haldia River 58 0 N Mile
Gangra Semaphore 62 0 N Mile
Sagar Lighthouse 79 0 N Mile
HOOGHLY SAND
KUKRAHATTI
DIAMOND HARBOUR ANCHORAGE
DIAMOND SAND
KALPI ANCHORAGE
BALARI
SITE FOR HALDIA DOCKS
HALDIA RIVER
HALDIA ANCHORAGE
RANGAFALA BAR
JELLINGHAM
SILVER TREE POINT
CHANNEL CREEK
KAUKHALI SAND
AUCKLAND
SAUGOR ISLAND
SAUGOR ANCHORAGE
SAUGOR CROSSING
EDEN CHANNEL
GUT. CHANNEL
LOWER LONG SAND
MIDDLETON

Fig. 2

ships of 26 ft. draft used the port for nearly 300 days. During the next twenty-five years, it had never been possible for the port to cater to such vessels for as many number of days. In fact, in 1961, the Port could not be opened to 26 ft. draft vessel for a single day. The deterioration of depths over different bars and crossings has varied from 1'-6" to 13'-6" since 1918.

The basic cause of the deterioration was understood decades ago, but so long as the basic factor of head water supply remained unsolved, the Commissioners had no alternative other than resorting to intensive dredging to provide day to day requisite depths for safe navigation of ships. The magnitude of the problem involved is illustrated by the increase in the dredging quantities from about 7 million tons in 1947-48 to about 21 million tons in 1967-68, with a corresponding rise in the cost of dredging and river maintenance from 73.73 lakhs to Rs. 735.25 lakhs in the same period.

The basic cause of the deterioration being the upland redistribution of sediment caused by the diminution of head water supply, restoration of adequate head water supply together with training measures remain the only course left for the rejuvenation of the river about which there has been remarkable unanimity in the views of experts concerned with the problem. The target of all efforts has been to restore the navigable depths available in 1936-38.

From the dredging point of view the bars and crossings of the Hooghly may be classified as follows :

(a) The upper bars which deteriorate gradually from the time the freshet finishes till it comes again.

(b) The crossings where the deterioration is due to the change in course of the deep channel when trying to adjust itself from the dry season to freshet conditions and *vice versa.*

(c) The bars where the shoaling is due to complex flow pattern created by the geography of the locality.

(d) The bars which are affected by the general instability of the sands as well as due to the uncontrollable ocean forces.

The bars in the estuary below Diamond Harbour indicate a gradual development over several years and the loss of depth is due to local deterioration of bars as well as to general deterioration of the upper tidal river. The bars and crossings above Hooghly Point are subject to seasonal changes influenced by the tidal regime of the river.

The tidal regime is the most important phenomenon on the Hooghly as it not only governs the time of steaming of ships and their draft, but it has an overall influence on dredging operation, dredging plant and method of dredging. Two of the most important features bound to the seasonal predominance of flood and ebb tides are (a) shoaling of the upper bars from the time the freshet finishes till it comes again, and (b) shifting of the navigable tracks from one bank to the other in trying to adjust themselves to the change in the course of the river from dry season to freshet season conditions and *vice versa.*

The shoals between Calcutta and Moyapur, known as the Low Water

Crossings, used by outward bound ships of light or moderate draft on falling tide, are subject to seasonal shoaling in varying degrees. The bars like Nazirganj, Panchpara, Sankrail, Munikhali start deteriorating on the cessation of freshets and have least navigable depths from March to May. The Eastern Gut Bar, in the Hooghly Point area where the natural seasonal flows are complicated by the geography of the river, shoals excessively during the strong flood tides of later February, March, April and May.

Apart from the loss of depths, changes in the alignment of navigable tracks over the crossings are also brought about with the change in the tidal seasons. Moyapur and Royapur Bars are typical examples where with the advent of the freshets, the dominating ebb current changes the flow pattern of the bar and the downward shifting of the tracks commences. The shift continues till the peak of the freshets and the navigable channel shifts to the lowermost tracks. Thereafter, due to falling freshets, the upward shifting of the tracks begins and with the onset of the flood season the navigable channel stabilises to the uppermost tracks (Fig. 3 A & B). The transition period is very crucial as there are insufficient depths both on the old and new tracks and dredging can not produce any great effect until the river is naturally ready for the change over.

Based on the method of navigation the dredging policy is directed towards development of suitable navigable depths on the governing bars in the first instance and maintenance of corresponding depths on other bars in the second. The dredgers are placed in position either before or at the first sign of deterioration so as to prevent shoaling taking place on the bars. Furthermore, in anticipation of the seasonal changes in the river the channel is prepared for the changes to speed the process and avoid any losses in navigable depth which occurs when the channel is left to the action of the natural forces alone.

The natural trends of the river at different seasons and states of tide, observed through many years, constitute a basic dredging routine but unforseen conditions always occur and the dredgers are required to be shifted to different areas at the very critical moment when at the end of the maintenance dredging improvement or corrective dredging starts. Consequently the continuity of the dredging squence is lost. Very often dredgers have to be deployed for considerable time in dredging a small patch of shoal which does not alter the state of the reach as a whole but is of vital importance for depth requirements for shipping. A specific example of deployment of dredgers in the year 1966 is shown in Fig. 4. While this indicates the general pattern of deployment of dredgers the actual barwise operational period and quantity removed vary from year to year due largely to the irregular fluctuations of the freshet hydrograph and redistribution of sediment which often disrupts the sequence of shoaling pattern.

The deployment of dredgers in 1966 as shown in Fig. 4 indicates that the problem is not of quantitative removal of material in a cyclic fashion but is of simultaneous deployment of a fleet of dredgers for the maintenance of navigable depths. At least four dredgers had all the time been deployed simultaneously dredging the bars between Calcutta and Balari. The transition period of the Fulta Point scheme led to the concentration of effort on the Hooghly Point area in that year where two and sometimes three dredgers at a time had to be deployed in an attempt to avert fall in depths. The breaks inbetween each dredging sequence (Fig. 4) do not necessarily mean that dredging during those days were not required but had been unavoidable under the operational system.

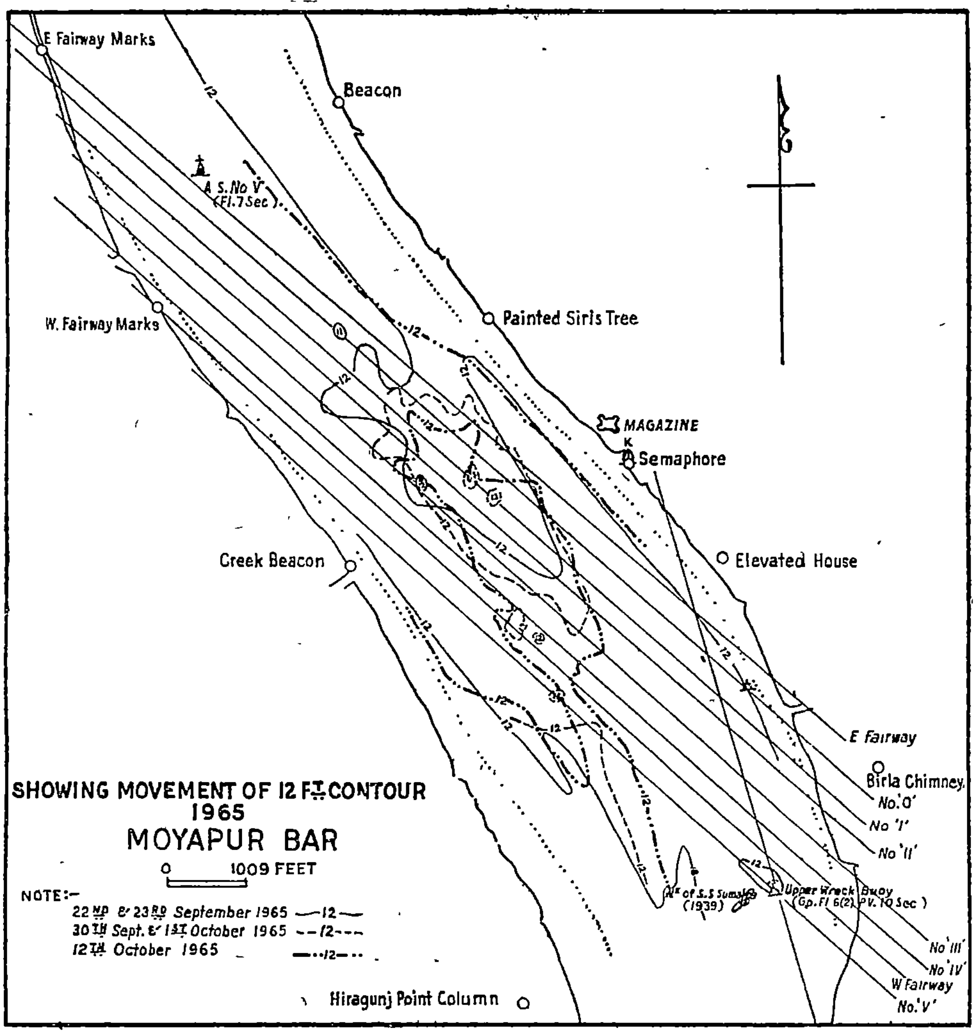


Fig. 3A

The basic factors which affect the production of a suction hopper dredger at any locality are the effectiveness of the dredging plant, distance to the dumping ground and the characteristics of the material dredged. The material dredged from the river bed consists mainly of sand and silt of different granulations. The percentage distribution of the grain sizes vary due to natural hydraulic selection, at times, even in the same locality. The median diameter of the grain sizes vary from 70 microns to 144 microns. The turn round time from dumping sites vary from 30 mins. to 1 hr. 30 mins on the bars of the river.

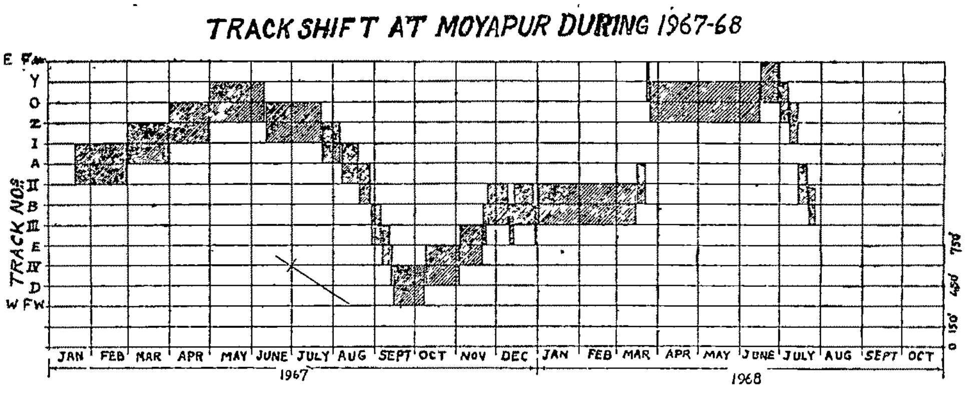


Fig. 3B

Besides the above, there are additional serious limiting factors for operations of a dredger on the Hooghly. The actual dredging time is directly related to the tidal condition and depth of water on the bars and decreases directly with the loss of depth. Therefore maximum production losses occur at sites where concentration of dredging is of vital importance. The presence of a shallower bar on way to the disposal ground of the dredger imposes limitations on the effective dredging time. Further, valuable dredging time is lost in providing clear passage to shipping over the bars. This has a particularly adverse effect on dredging time as shipping generally traverses a bar on a rising tide when the dredger has the floatation for effective dredging. Operations of a dredger in the narrow channels and strong tides of the Hooghly, often with barely six inches of clearance under the keel is generally hazardous and impose considerable strain on the dredgers' personnel and equipment. Since dredging operations in the upper reaches depend solely on visual judgement, non-visibility of marks or transits in fog or heavy rain imposes limitations on the operational time of a dredger. Dredging operation at night above the Eastern Gut Bar is not considered safe and practicable. Again the flow conditions on the Eastern Gut are so adverse on the flood tide that dredging is normally restricted to the ebb tide period only.

In the estuary where accurate position fixing of the dredger, which is an essential

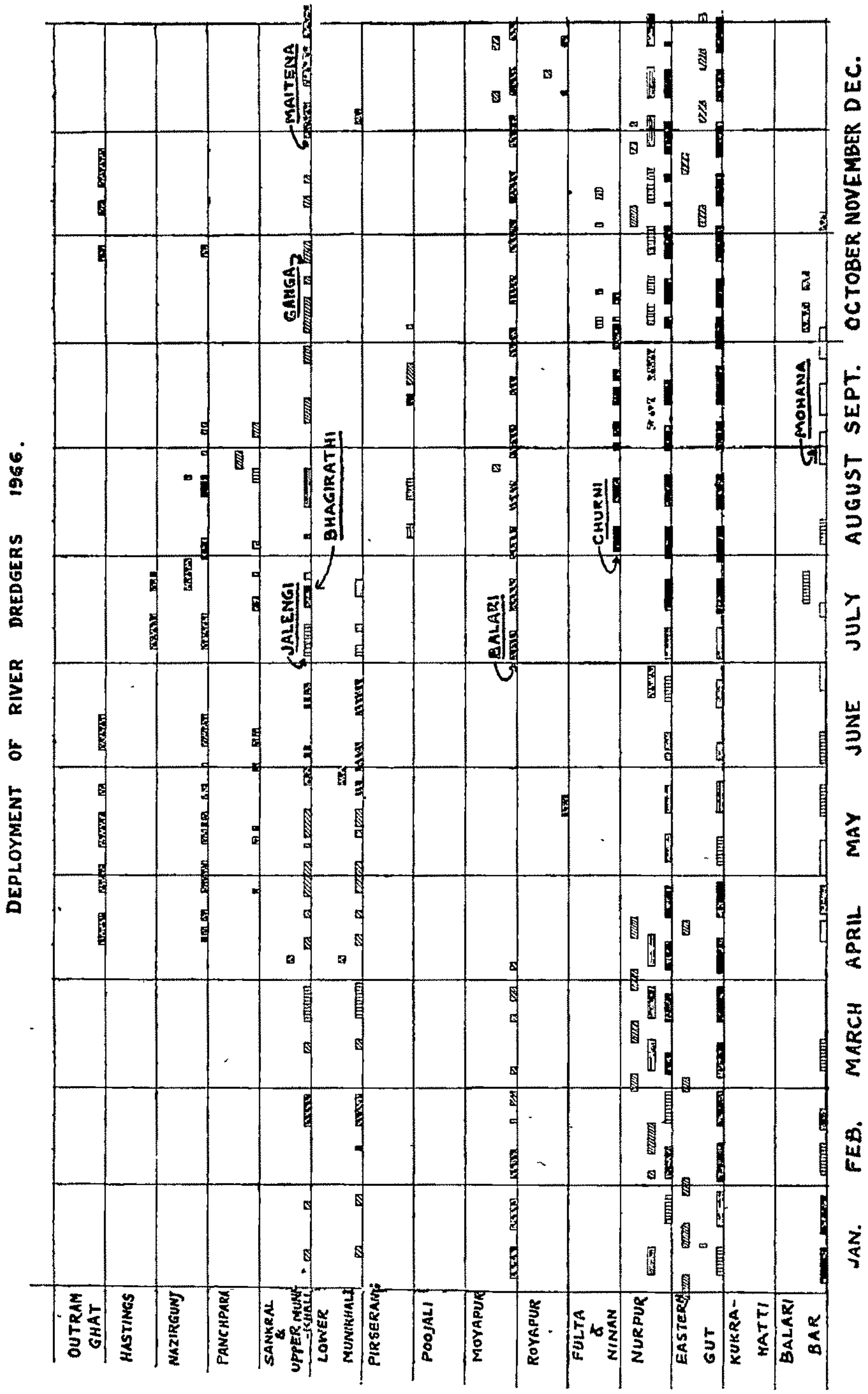

DEPLOYMENT OF RIVER DREDGERS 1966.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
OCTOBER
NOVEMBER
DEC.
OUTRAM GHAT
HASTINGS
NAZIRGUNJ
PANCHPARA
SANKRAL & UPPER MUNI-KHALI
LOWER MUNIKHALI
PIRSERANG
POOJALI
MOYAPUR
ROYAPUR
FULTA & NINAN
NURPUR
EASTERN GUT
KUKRA-HATTI
BALARI BAR
MAITENA
GANGA
JALENGI
BHAGIRATHI
BALARI
CHURNI
MOHANA

Fig. 4

part of the operation, is extremely difficult by visual observation, proper functioning of the Hi-Fix system is most important. Often failure of the system in rain or squalls or breakdown from any other cause results in considerable over dredging. Although the estuarian dredger is designed to operate all round the year, the weather in the Hooghly estuary can become so violent that the dredger has to retreat to the safety of sheltered waters interrupting dredging operations.

In the port area the siltation alongside jetties, lock entrances, river moorings is governed by different principles from hydraulic point of view, including the characteristics of spoil. Even the dredgers required are different type than used in the river and their problems are also different. The dredging alongside jetties and river berths can be carried out only when they lie vacant. Similarly the locks and lock entrances are dredged only when these are not used by shipping which must be given the priority. The interruptions of dredging operations at the locks and lock entrances has an adverse effect on the output of the port area dredgers. The bucket dredgers cannot operate in the river during the bore tides and are brought inside the impounded docks as in the case of merchant ships. The resultant congestion in the docks becomes responsible for no berth being available for dredging and the dredgers are forced into idle hours.

The disposal of the spoil dredged from the Hooghly also presents a difficult problem. In general two choices are usually available for disposal of dredged material. The spoil can be placed in open water or removed completely ashore. Several variations of these methods are possible, but all are basically reduced to these choices. The dredging sites in the river being situated far from the sea and due to industrial and agricultural development no suitable large shore disposal areas being available, the present practice is to freely dump the spoil into carefully selected areas close to the dredging sites. Though such dumping sites have been most carefully selected with the aid of radio active and flourescent tracer experiments to ensure that the material does not immediately find its way back to the dredging site, it certainly cannot improve the overall capacity of the river. Whilst engaged in desperate struggle to maintain navigable depths, the Commissioners could not consider any reduction in output of dredgers that must result from any scheme of shore disposal of spoil and until recently the dredging policy was not greatly concerned with the state of the river as a whole.

However when the predicted dredging output is reduced, an alternative method for the disposal of dredged spoil would merit the most active consideration.

There can be no doubt that the problems of dredging in the Hooghly are real and perhaps unique. The operation of large suction dredgers in the narrow, tidal, shoaling channels requires from the Dredger Master professional skill of the highest order. The men who have manned these dredgers on the Hooghly in this difficult period of the last twenty years have fought with great skill a hard unrewarding battle against nature.

For the preservation of shipping route

to the Port of Calcutta a comprehensive improvement plan of the Hooghly-Bhagirathi has been undertaken in the construction of the Farakka Barrage Project and implementation of river training measures. As a result of this it has been estimated that the volume of dredging which was about 10.7 million tons upstream of Balari Bar in 1967-68 would decrease to 3.2 million tons by 1974. On stabilisation of the channels in the post-Farakka conditions together with the completion of training measures the dredging by 1981 would be of the order of 2.5 million tons.

In anticipation of the expected improvement and largely due to the improved performance of the latest dredgers, the Commissioners have disposed off three of their dredgers in the course of the last two years. The dredger "Balari" after 60 years of splendid service was decommissioned in 1967 and dredgers "Ganga" and "Pansy" were sold to Cochin and Vizag Ports respectively in 1968. It may perhaps now be said with some confidence to have seen the worst and can look towards a hopeful future. With the river training works so far executed beginning to show results and the Farakka Barrage Project nearing completion it may be expected, by about 1975-76, to return to the almost optimum conditions of the river that existed in 1938.

REFERENCES

Bernstein, Henry T. *Steamboats on the Ganges.*
Braine, Alfred *Inland services of Bengal (Manuscript).*
Hydraulic Study Department, *Technical Reports and Specific Notes,* C.P.C.
Institute of Port Management *Proceedings of the Symposium on Problems of Navigation on the Hooghly,* 1967, C.P.C.
Leonard, Hugh, *The Report on the River Hooghly.*
Marine Department, *Annual Administrative Report,* C.P.C.
Oag, T. M. *Report on the River Hooghly and its Headwaters.*
Pinches, Capt. G. R. I. *Lecture Notes—Second Orientation Course—Institute of Port Management,* C,P.C.
Reaks, H. G. *Report on the Hooghly River and its Headwaters. Vol. I.*
Szawerhowshi, P. *Report on the Dredging and Reclamation Problem on the River Hooghly,* Port Development Expert—UNTAO.
Vernon-Harcourt, L. F. *Report on the River Hooghly.*

ELECTRICAL ANALOGUE MODEL AS AN AID TO THE STUDY OF HOOGHLY RIVER PROBLEMS

K. K. BANDYOPADHYAY AND N. C. MAZUMDER

Abstract

The problems of the propagation of tidal waves through estuaries and branches are complex. Analytical study of such a system becomes difficult due to the non-linear nature of the differential equations that describe the propagation through such a system.

Recourse is usually taken to hydraulic, mathematical or electrical analogue, model studies for investigating the system behaviour under various boundary conditions.

In the electrical analogue model, hydraulic parameters are simulated and scaled into corresponding electrical parameters. The design of such a model was developed in this laboratory from the concept of low frequency non-uniform non-linear transmission line. It has developed into a valuable economic aid for studying the system under various conditions of the channel (including upland discharges), and its boundary. It is extremely simple to operate.

The examples have been given from River Hooghly.

The propagation of tidal wave through any river system is mainly governed by the channel parameters, head water supply quantum and the wave amplitude. One of the channel parameters (i.e., the friction) being non-linear in nature, distorts the wave form more and more with the landward progress of the tide. The flooding time and ebbing time has nearly equal distribution at the sea face, but after distortion, the former gradually decreases while the latter increases. The velocities in these phases of tide, change accordingly for obvious reason. This brings about a change in the flood/ebb predominance characteristics. This predominance mainly decides the sediment drift pattern through the system. The quantum of head water supply also is responsible for bringing about a further change in the above said predominance characteristics. Lastly, the wave amplitude changes from day to day from season to season, influencing the sediment drift pattern likewise. All these, in turn, help altering the channel parameters (i e., width, depth), thus forming a vicious circle. These alterations play a decisive role in creating "partial barrier effect" to the propagating tide or forming "bore".

Thus, it becomes often necessary to study the propagation through such a channel system. No doubt, prototype studies yield valuable information, but whenever corrective engineering works are contemplated, recourse is usually taken to model studies, be it hydraulic, mathematical or electrical analogue.

The solution to the physical system of the estuary or tidal channel may be attempted by substitution of another analogous physical system, where the quantities may be quite different. The general purpose of working with such a model is to determine or predict the response of the system which otherwise cannot be analysed directly without excessive difficulty or expenses. Due to unprecedented development in the field of electronics in the last decade, analogue model studies have been widely advocated. The reason being that the electrical measurements have reached fairly high degree of accuracy than any other measuring technique. Moreover, in such a model various schemes for improvement can be checked rapidly. The problem can be formulated under various altered field conditions to strike at the optimum design, finally to be tried in another supplementing model These studies would not involve any additional expenditure over the existing model, compared to any other type.

Einstein and Harder (1959) studied the effect of salinity barriers and other engineering constructions in the tidal compartment of California and obtained valuable information. Harder and Masch (1961) extended this technique to the study of tidal propagation through the Panama Canal, where tides of differing amplitude and phase, simultaneously enter through Pacific and Atlantic ocean-ends respectively. Schoenfeld and Stroband (1964) have developed one such model for the study of the tidal propagation through the delta works of the Netherlands.

THEORY

The tidal propagation through a river system may effectively be described by the following well-known simplified partial differential equations (Bandyopadhyay and Das Gupta, 1969).

$$\frac{\delta q}{\delta x} + b\,\frac{\delta h}{\delta t} = 0$$

$$\text{and } \frac{\delta h}{\delta x} + \left(\frac{1}{gbd}\right)\frac{\delta q}{\delta t} + \frac{q/q}{C_c^2 b^2 d^3} = 0 \qquad \ldots (1)$$

where q : discharge
h : tidal elevation
b : width of the flow channel
d : average depth of the channel
C_c : Chezy's friction coefficient
g : acceleration due to gravity
x : distance
t : time

The above mentioned system has a closer analogy in a transmission line, propagating low frequency electromagnetic wave. The corresponding approximate partial differential equations describing the propagation are :

$$\frac{\delta i}{\delta x}+C\frac{\delta e}{\delta t}=0$$

$$\text{and } \frac{\delta e}{\delta x}+L\frac{\delta i}{\delta t}+Ri=0 \quad \dots \quad (2)$$

where i : current

e : impressed voltage

L : inductance per unit length of the line

C : capacitance per unit length of the line

R : resistance per unit length of the line

x : distance

t : time

In order that the electrical transmission line be accepted as analogue of the tidal channel, the termwise correspondence with proper functional dependence has to be sought. Comparing equation sets (1) and (2) one obtains the following analogy between the two systems :

$$h \equiv e$$

$$q \equiv i$$

$$\frac{1}{gbd} \equiv L \text{ (system inertia)}$$

$$b \equiv C \text{ (system storage)}$$

$$\text{and } \underset{c}{\frac{q/q}{C^2b^2d^3}} \equiv R \text{ (system friction)}$$

(It is interesting to note that usual electrical transmission lines are uniform and their parameters linear, while the actual tidal channel is non-uniform and its parameters are non-linear).

In a tidal channel, the system parameters, i.e., intertia, storage and friction changes with the state of the tide, while in our corresponding analogue-system just described, they are normally independent of the impressed signal (voltage). In order to appreciate the situation fully, the simulation must have to be attempted by discretising the system and designing special circuits with prototype correspondence. Out of these three parameters, the non-linear friction parameter plays the most important role in bringing about the wave-form distortion.

Special circuit has been designed in this laboratory to simulate the hydraulic friction with its proper functional dependence (Bandyopadhyay and Mazumder, 1967). The inertia and storage element was set at mean tide level value for every reach.

In order to relate each of the parameters with those of the prototype, appropriate scale factors (Bandyopadhyay and Mazumder, 1969) must be chosen. In fact, only two independent scale factors need be chosen. Thus, if one chooses scale factors for tidal elevation and tidal "impedance" the other scale factor, i.e., that for response becomes automatically fixed. With these scale factors, the prototype parameters as obtained from survey data are converted to the corresponding lumped electrical parameters.

Lumping of distributed parameters is important in analogue simulation, because it permits the construction of analogue model using lumped electrical elements, which are easier to design, manipulate and specify with high accuracy and precision. Such process of lumping, in turn, introduces error in the propagation characteristics of the analogue model simulating the prototype. In order to minimise the error, the number of sections to represent the whole tidal river should be increased. It has been shown (Bandyopadhyay and Mazumder, 1969) that to represent the River Hooghly, 14 sections are optimum and the error lies within 3 per cent.

THE MODEL

To investigate the behaviour of a tidal channel under varied boundary conditions, especially to study the effect of contemplated corrective engineering works in tidal zone, an electronic analogue model of the River Hooghly has been designed in this laboratory. The tidal channel between Saugor at the sea face and Bansberia at the landward end, was divided into 12 sections, according to the location of the tidal observatory stations (Fig. 1). The main tributary, the River Rupnarain, was simulated in a similar fashion and was connected to the main channel at the corresponding point of the model. The main channel as well as the tributary was terminated by proper impedances, i.e., a suitable resistance-capacitance network equivalent to the labyrinth temination of a hydraulic model.

The tides at Saugor (sea face) is not purely sinusoidal Therefore, to reproduce the sea face tidal wave-form, a "tide generator" was designed. Sinusoidal wave from an audio-signal generator was fed to a wave shaper circuit (forming the tide generator) and then to the analogue model through a proper impedance matching circuit.

Each section of the prototype was represented by an inductance simulating inertia, a capacitance for storage and a friction simulator unit for the corresponding friction of the channel. All these components were arranged in "π"-form and the sections were connected in tandem (Fig 2). The friction simulator units for a particular section was set depending on the value of the Chezy's constant appropriate for that section. The responses at the points corresponding to the particular tidal gauge station in the prototype were observed on eight channel oscilloscope. The typical simultaneous responses of this model corresponding to the tidal elevetions at different observation stations located on the Hooghly banks are presented in Fig. 3A oscillogram.

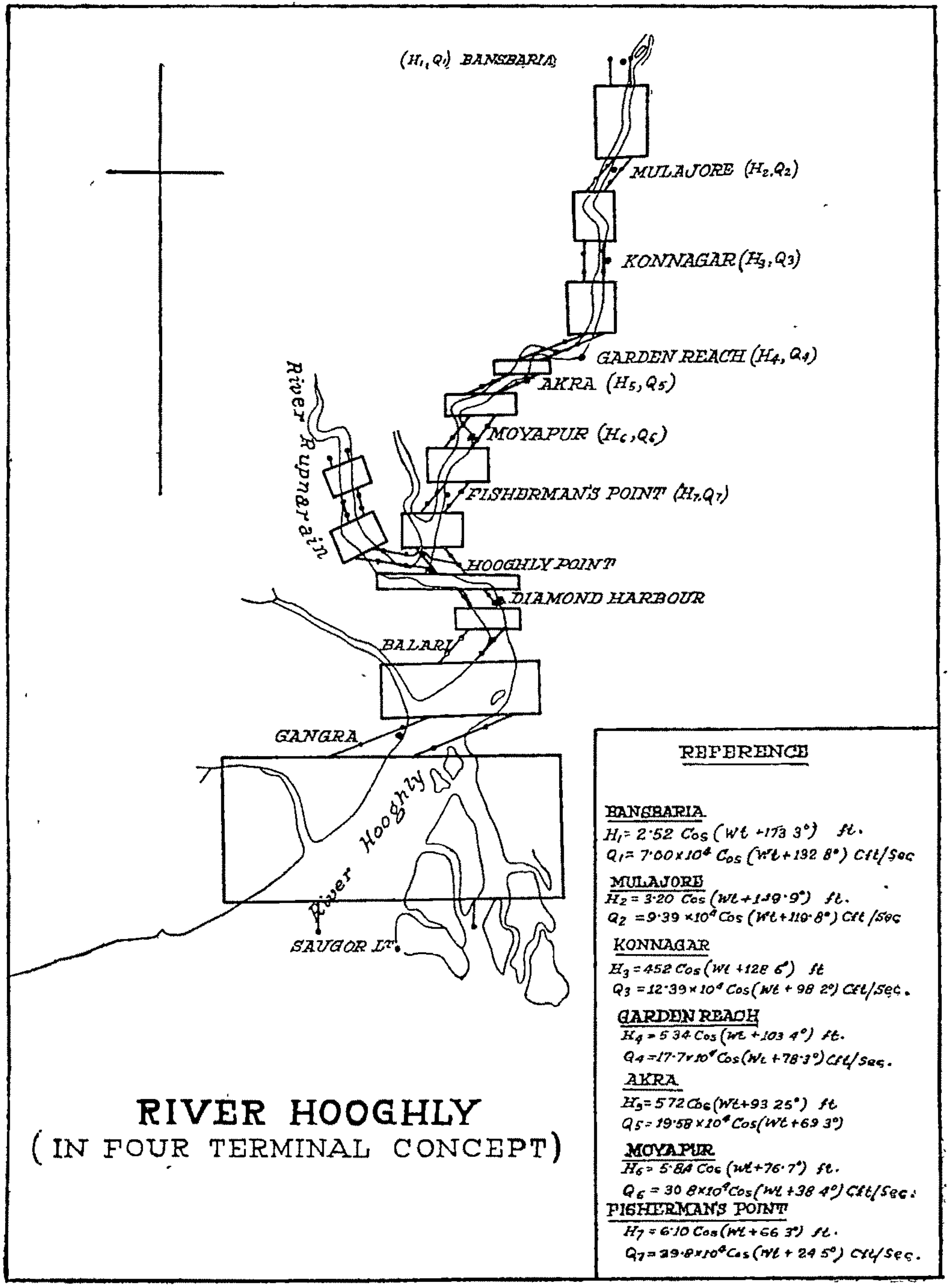
EXPERIMENTS CARRIED OUT WITH THE MODEL FOR THE STUDY OF HOOGHLY RIVER PROBLEMS

1. Change in tidal elevation wave-form under various head water supply conditions. These wave-forms were carefully analysed with the help of electronic wave analyser.
2. Partial barrier effect and consequent reflection of tidal energy under altered boundary condition at the tidal apex, both under (a) existing head water supply and (b) altered head water supply situation.
3. The analysis of discharge curves (a typical oscillogram is shown in Fig. 3B) under various changed boundary conditions and head water supply helped assessment of flooding and ebbing velocities. These, in turn, were used to determine the flood/ebb predominance characteristics and were helpful to locate the zones of siltation.

DISCUSSION

(a) The system error due to lumping was reasonably small.

(b) The design of signal dependent inertia and storage, though not as important as friction, needs attention for further improvement of the model.



RIVER HOOGHLY
(IN FOUR TERMINAL CONCEPT)

REFERENCE

BANSBARIA
$H_1 = 2{\cdot}52 \; Cos \; (Wt + 173\ 3^\circ)$ ft.
$Q_1 = 7{\cdot}00 \times 10^4 \; Cos \; (Wt + 132\ 8^\circ)$ Cft/Sec

MULAJORE
$H_2 = 3{\cdot}20 \; Cos \; (Wt + 149{\cdot}9^\circ)$ ft.
$Q_2 = 9{\cdot}39 \times 10^4 \; Cos \; (Wt + 119{\cdot}8^\circ)$ Cft/Sec

KONNAGAR
$H_3 = 452 \; Cos \; (Wt + 128\ 6^\circ)$ ft
$Q_3 = 12{\cdot}39 \times 10^4 \; Cos \; (Wt + 98\ 2^\circ)$ Cft/Sec.

GARDEN REACH
$H_4 = 5\ 34 \; Cos \; (Wt + 103\ 4^\circ)$ ft.
$Q_4 = 17{\cdot}7 \times 10^4 \; Cos \; (Wt + 78{\cdot}3^\circ)$ Cft/Sec.

AKRA
$H_5 = 5\ 72 \; Cos \; (Wt + 93\ 25^\circ)$ ft
$Q_5 = 19{\cdot}58 \times 10^4 \; Cos \; (Wt + 69\ 3^\circ)$

MOYAPUR
$H_6 = 5{\cdot}84 \; Cos \; (Wt + 76{\cdot}7^\circ)$ ft.
$Q_6 = 30\ 8 \times 10^4 \; Cos \; (Wt + 38\ 4^\circ)$ Cft/Sec.

FISHERMAN'S POINT
$H_7 = 6{\cdot}10 \; Cos \; (Wt + 66\ 3^\circ)$ ft.
$Q_7 = 29{\cdot}8 \times 10^4 \; Cos \; (Wt + 24\ 5^\circ)$ Cft/Sec.

Fig. 1

In fact, the signal dependent inertia is under development and would be incorporated in the model shortly.

(c) The simplified equation adopted in equation set-1 has purposely neglected the convective acceleration term which plays very important role during bore tide situation and needs careful consideration.

CONCLUSION

(a) The inexpensive analogue model designed in this office has proved to be a valuable tool for rapid assessment of system responses under altered channel and boundary conditions.

(b) All these experiments confirmed that at least a head water supply of 40,000 cfs. was necessary for the maintenance of the River Hooghly.

ACKNOWLEDGMENT

The authors are grateful to Dr. S. K. Bhattacharya, Chief Hydraulic Engineer, Calcutta Port Commissioners, for his suggestions, help and encouragement during the progress of the study.

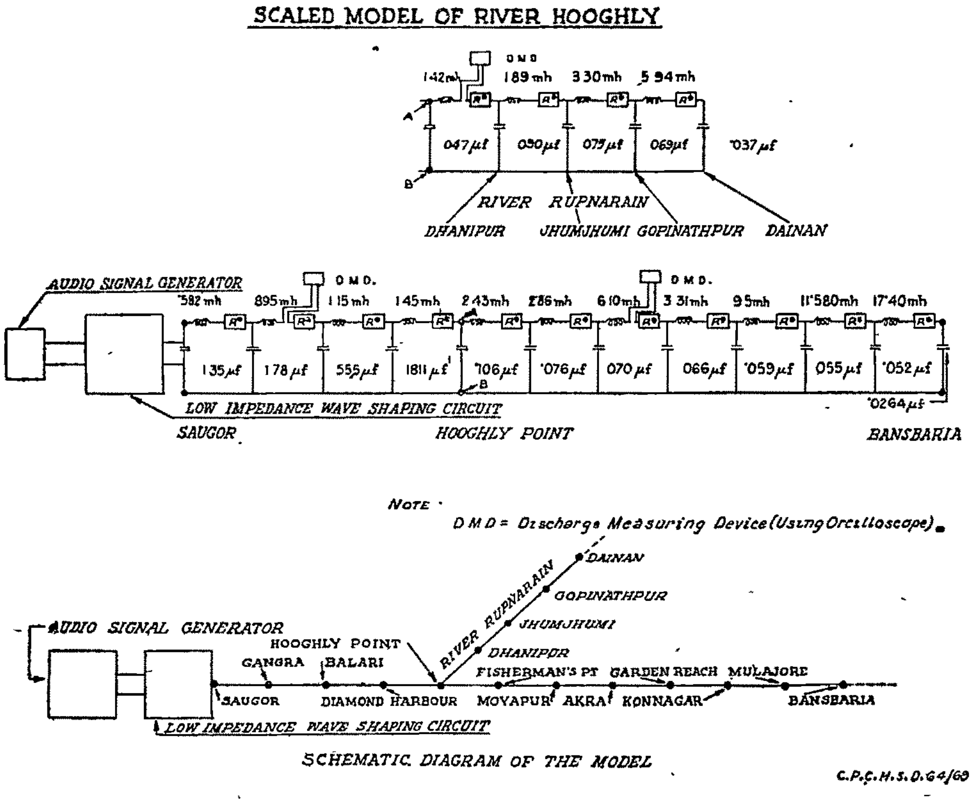


Fig. 2

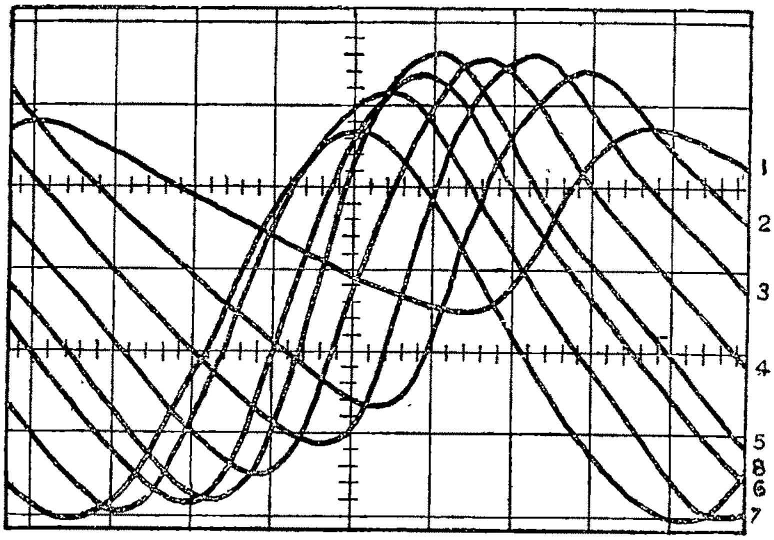


Fig. 3A

Simultaneous Oscillograms of the tidal elevation curves at different station (marked serially 1 to 8) as obtained from the model. Curve 1 represents for station Bansbaria, 2 for Konnagar, 3 for Akra, 4 for F'Point, 5 for Diamond Harbour, 6 for Balari, 7 for Gangra and 8 for Saugor.

Scale : Vertical 0.2 m/small div.
Horizontal 20 min./small div.

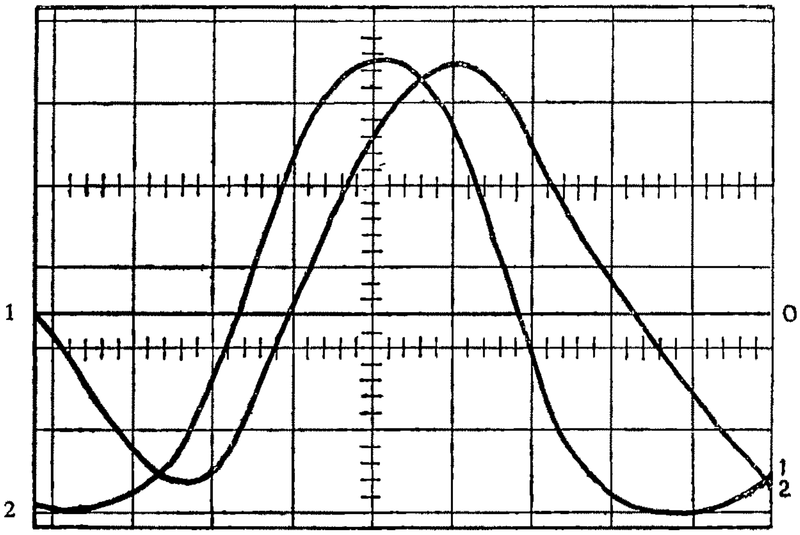


Fig. 3B

Oscillograms of the tidal elevation at Gangra (curve marked 1) and discharge curve (marked 2) at the Gangra end of the Gangra Balari Section.

Scale : (a) Discharge curve : 16 x 10^3 m^3 / sec per small div.
(b) Tidal elevation curve 0.2 m/small div.
(c) Time scale : 20 min./small div.

REFERENCES

Bandyopadhyay, K. K. and Das Gupta, S. (1969) : *Identification of the Parameters of a Tidal Channel from Simulation and other Approaches.* Proc. Fourth Congress of International Federation of Automatic Control, (Warsaw).

Bandyopadhyay, K. K. and Mazumder, N. C. (1967) : *Design of a Tidal Channel Friction Simulator.* Int. J. of Electronics (London), Vol. 23, No, 6, pp. 519-31.

Bandyopadhyay, K. K. and Mazumder, N. C. (1969) : *Scaling of Tidal Channel Parameters for the Construction of Electronic Analogue Model.* Int. J. of Electronics (London), Vol. 26, No. 2, pp. 145-152.

Bandyopadhyay, K. K. and Mazumder, N. C. (1969) : *Error in the Propagation Characteristics of the Lumped Analogue Model of a Tidal Channel.* Int. J. of Electronics (London), Vol. 27, No. 3, pp. 231-235.

Einstein, H. A., and Harder, J. A. (1959) : *An Electric Analogue Model of a Tidal Estuary.* Proc. A.S.C.E., 85, WW3, 2173.

Harder, J. A. and Masch, F. D. (1961) : *Nonlinear Tidal Flows and Electric Analogues.* Proc. A.S.C.E., 87, WW4, p. 475.

Schoenfeld, J. C. and Stroband, H. J. (1964) : *Tidal Research by Hydro-Electrical Analogy*, Paper III. 8. Department of Water Control and Public Works (Netherlands).

PART THREE

ECONOMIC ACTIVITIES RELATED TO THE BHAGIRATHI-HOOGHLY RIVER SYSTEM

D. K. BOSE AND S. K. BANERJEE

Abstract

The continuing decline in the headwater supply in the Bhagirathi-Hooghly river from the Ganga over the past centuries have been seriously affecting the economic activities relating to the river system. Adverse effects are noted in the level of activities in the Calcutta Port, the river transport system, fishing and trading dependent on the river system. The Bhagirathi-Hooghly being the mainstay of the network of rivers and canals in West Bengal, the decay in the tributaries and canals connected with it have transmitted the consequences to the economy of the countryside in the hinterland. Calcutta city and other municipalities on the river have been facing problems of drainage and water supply to the urban population. The Farakka barrage project provides a silver lining to the cloudy picture. The prospect of a revival of the economic activities through the regeneration of the river by providing additional supply of water to it as envisaged in the Farakka project is examined in the paper.

A large river system in a country confers not only direct benefits in terms of facilities for navigation, irrigation and other uses of water-resource itself, but it also affects in various ways the economy of the countryside in the hinterland.

By providing a convenient and very often cheaper mode of transport for the commodities produced or distributed in the countryside the river system helps to keep down the prices of the produce, thereby extending the market for them. Transport and fishing activities over the river calls for creation of industries for building and repair of the river crafts and other equipments.

The economics of a river system can be analysed at two levels. The first level would deal with the economics involved in the utilisation of the waters resource itself. It concerns the relative economic merits of the use of water, alternatively for navigation, irrigation, power generation, or for other uses like water supply to the riverside towns. There has been limited success in devising an effective criterion on the basis of cost-benefit analysis in choosing between the alternatives in the use of water resources. Maass and others (1962) have discussed the problems involved in the evaluation of the alternatives in the overall planning of a water-resource system. An extensive reference to the existing literature on the subject is also given in the publication.[1]

The second level of the economic analysis would consist of the study of the productive activities generated by the various uses of the water-resource. It may be seen that the analysis at the first level is very much dependent on the results of analysis at the second level.

In the present scheme for the Bhagirathi-Hooghly system, the prospect of power generation from the river is ruled out. As we propose to deal primarily with the possibilities related to navigational facilities offered by the river we shall ignore the problem of choice between other alternatives, that is an analysis at the first level. We shall nevertheless be discussing other uses of the rivers in passing.

DECLINE OF THE BHAGIRATHI-HOOGHLY

The Bhagirathi, known in its lower course as the Hooghly, is the main river in West Bengal. Branching off from the Ganga near Jangipur at the northern boundary of Murshidabad district, the Bhagirathi-Hooghly runs a course of about 320 miles before flowing into the Bay of Bengal. Winding its way through seven districts of West Bengal and receiving a number of tributaries, the river used to be the mainstay of the intensive network of rivers and canals of the State till a few centuries back.

Bounties that the generous river distributed through her system enriched historic towns on her banks. Flood-flush through the system yielded fertility to the soils, kept the river channels free and navigable over the years. Time was when the State was considered a riverine country. Large trading vessels used to ply freely up the tributaries of the Bhagirathi-Hooghly. Things turned for worse from around 17th century till which time the Ganga was flowing mainly through the Bhagirathi-Hooghly. Thereafter, the river showed a tendency to flow through its other branch, the Padma, which gradually emerged as its major branch. The condition of the Bhagirathi continued to deteriorate further. "Over years, the head water supply decreased and now there is no supply for about 10 months in a year"[1] (Bhattacharya, 1969). There appears to be an acceleration in the rate of decline in headwater supply also. "In 1938 the Bhagirathi, the upper part of the non-tidal Hooghly, which used to bring a peak of about 100,000 cusecs of fresh water-flow dwindled in recent years to about 55 or 60 thousand cusecs and there is no assurance that the mouth of the Bhagirathi which draws water from the Ganga might not close altogether" (Bhattacharya, 1969). The once-mighty Bhagirathi deteriorated to the state of a spill channel only.

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[1] Maass *et al.* Design of Water Resource Systems.

DISLOCATION OF RIVER TRAFFIC

The stagnation in the principle river system in West Bengal naturally led to a decline in the economic activities based on it. As the level of water decreased in the Bhagirathi-Hooghly it became increasingly unsuitable for plying the country boats too. The bigger sized boats were to gradually give way for lack of sufficent depth of water. The irregularity in the supply of water in adequate depth discouraged the transport services generally. Even the fishing activities over the river gradually declined.

An indirect effect of deterioration in transport facilities was the elimination of economic enterprises like traders, craftsmen, agricultural producers, etc. who were surviving marginally in their activities through cheaper transport costs. There was thus a check in the rate of growth of the economic activities in the rural areas. While the development of road and railway traffic partly compensated for the loss of navigational facilities on the river, the net result has been the loss of trade and occupation of thousands of people involved in river transport and fishing activities. The Joint Steamer Companies, which used at one time to deploy nearly a thousand vessels of various types and sizes over the course of the Ganga and moved goods and passengers between Bengal, Bihar and Assam, found its operations to be uneconomic due to the difficulties of navigation and competition from rail and road transport systems and terminated its services from the end of 1957. The direct services between stations in Bihar and Calcutta could be performed only for the two months in the monsoon season during which the Bhagirathi remained connected to the Ganga. The river services between Calcutta and Assam by other agencies continued for some more time by using the river routes through East Pakistan (Bangla Desh) via Goalundo. This too discontinued after the outbreak of hostilities between India and Pakistan in 1965. Sizable movement of traffic over the Hooghly is now restricted to Industrial belt along the greater Calcutta area only

PROBLEMS IN CALCUTTA PORT ACTIVITIES

The decline in the headwater supply in Bhagirathi-Hooghly affected seriously the activities of the Calcutta Port. The weakening of the seaward tides in the Hooghly premitted the strong tidal waves from the sea to deposit a cumulating volume of sand on the river bed, eventually resulting in a fall of navigable depths for the Port. It is revealing that the volume of total seaborne cargo handled by the Port over last 40 years has been nearly stationary, hovering between 8 million tonnes and 11 million tonnes. As a matter of fact, the peak figure of 11 million tonnes attained in 1964-65 compares with the same volume attained as early as in 1929-30 (Roy, 1969).

A pernicious effect of the diminishing headwater supply is observed in the increase in the frequency and intensity of the bore tides over the Hooghly (Batra, 1968). This has been mainly due to the increase in the tidal range in the upper reaches of Hooghly and the decrease of depths in the river Hooghly. While in 1947 the number of bore days was only 70, in 1962 there were as many as 161 days of bore tides on the Hooghly. The enormity of the problem can be appreciated from the fact that the vessels lying in the riverside berths are required to be shifted into the docks during the bores to save them from parting their moorings and more than 60 per cent of the berths in the Port are situated on the river The deterioration of the river has affected the drafts to such an extent that while in 1938 the number of days the larger vessels of 26 feet draft could not use the Port was 74, in 1966 it rose to a figure as high as 282. No wonder, the Port authority has been finding it difficult to maintain the number of ships handled by them to a reasonable level. The number of ships entering the Port of Calcutta has been around 1800 over the past decade. The figure even declined to a level around 1600 during 1965-67 (Mukherjee, 1968).

POPULATION IN THE RIVERINE DISTRICTS

The Bhagirathi-Hooghly river system has nevertheless continued to play a a significant role in the overall economy of West Bengal We may recount here a few relevant facts to help appreciate the position. Table 1 shows the area, the population and its growth between the inter-censal period 1951-1961 for the seven districts through which the Bhagirathi-Hooghly flows.

TABLE—1

Area and population of the riverine districts in West Bengal

District	Area (sq. miles)	Percentage of area	Population 1961	Percentage of the State's population 1961	Density of population 1961	Percentage change over 1951 population 1961
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Howrah	560.1	1.6	2038477	5.8	3639	+ 26.51
Hooghly	1212.1	3.5	2231418	6.4	1841	+ 39.10
24 Parganas	5639.9	16.5	6280915	18.0	1114	+ 36.27
Murshidabad	2072.1	6.1	2290010	6.6	1105	+ 33.47
Nadia	1509.0	4.4	1713324	4.9	1135	+ 49.64
Calcutta	32.3	0.1	2927289	8.4	90628	+ 8.48
Burdwan	2705.4	7.9	3082846	8.8	1139	+ 40.66
Total	13730.9	40.1	20564279	58.9	1498	+ 32.03
Total (excluding Calcutta)	13698.6	40.0	17636990	50.5	1287	+ 36.96
West Bengal	34194.1	100.0	34926279	100.0	1021	+ 40.49

Source : District Census Hand Book—1961 Census.

The seven districts covered 40 per cent of total area and comprised about 59 per cent of the population of the State in 1961. The density of population in each of the districts has been above the average for the State. The growth rates for population in five of the districts have been lower than the average for the State. Besides other factors the high density of the population in the districts might have discouraged in-migration into the areas. Part of the difference can be ascribed to the consequences arising from the decling river system.

TABLE—2

Workers in fishing and river transport occupation in the riverine districts

District	Occupation	
	fishermen and related workers	deck ratings (ship) barge crews and boatmen
(1)	(2)	(3)
Murshidabad	10917	559
Hooghly	4119	1305
Howrah	4641	2498
Nadia	7643	510
Burdwan	4760	562
24 Parganas	5124	3007
Calcutta	561	7920
Total	37765	16361
West Bengal	54376	18709

Source : Census of India, 1961,
General Economic Tables, W. B. & Sikkim,
Vol. XVI, Part II, B (ii).

Table 2 shows the number of workers in fishing and river transport occupation in the seven districts on the Bhagirathi-Hooghly as found during 1961 census. The districts accounted for 69.4 per cent of all workers in fishing and related workers in West Bengal. Although fishing on the river is understood to be decreasing fast, water from the river is impounded by nature or by artificial means by man to serve as fisheries to a significant extent. Deck ratings and boatmen are not separately shown in the census occupational classification. However, subtraction of the figure 7920 for Calcutta will remove the ship ratings from the total, leaving some underestimated number of boatmen for the six districts on the river. The river system not unnaturally accounts for 87.4 per cent of the total workers in river transport occupation in the State.

In Table 3 we present the figures for the population in 56 towns situated on the bank of the river and compare them with the population in the urban areas of the district. The list of the towns with their respective population is given in table A1 in the Appendix. Excepting for Burdwan and Calcutta, the population in the riverside towns comprised 53 to 91 per cent of the urban population in the respective districts (col. 6). Only 3 towns in Burdwan are situated on the small stretch of the district by which the river flows. Calcutta city forms a district by itself. On the whole 67 per cent of the urban population of the State live in the riverside towns. The riverside towns being historically older their rates of growth have been slower than those for the other towns as indicated by the average figures under colum (5).

RIVERSIDE INDUSTRIES

The river system has traditionally been found advantageous for the location of industries on its banks. In the early days of industrial development in India

TABLE—3

Population and its growth in the towns by the Bhagirathi-Hooghly and the urban areas of West Bengal

Districts	Population in riverside towns 1961	Percentage variation over 1951	Total urban population 1961	Percentage variation over 1951	(2) as percentage of (4)
(1)	(2)	(3)	(4)	(5)	(6)
Murshidabad	135024	+ 22.68	195464	+ 44.87	69.08
Hooghly	529264	+ 38.05	579283	+ 46.71	91.37
Howrah	741595	+ 41.98	825092	+ 57.97	89.88
Nadia	167569	+ 46.88	315338	+ 51.53	53.14
Burdwan	53743	+ 31.06	561066	+ 73.20	9.58
24 Parganas	1187889	+ 36.92	1997959	+ 64.29	59.46
Calcutta	2927289	+ 8.48	2927289	+ 8.48	100.00
Total	5742373	+ 21.23	7401491	+ 31.03	77.58
Total (excluding Calcutta)	2815084	+ 38.10	4474202	+ 51.66	62.92
West Bengal	5742373	+ 21.23	8540842	+ 35.97	67.23

Source : District Census Handbook—1961 Census.

large number of textile industries were sited by the river side because of the prevailing importance of river transport in the receipt of agricultural raw materials and the delivery of the products by the industries. Industries also found it convenient to draw on the water resources of the river and an easy way of discharging the waste products in it. The pollution of water due to the latter has lately been causing serious concern. A sizable proportion of industrial units of certain types is still to be found situated on the river. Table 4 shows the number and proportion of industrial units along the river for the riverine districts.

The number of units being of varying sizes it is difficult to estimate from it their relative importance in terms either of employment or of total product. In terms of number, however, a large proportion of the industrial units are located in the riverside towns. Nearly two-thirds of the jute mills in the six districts are found on the riverside. 61 per cent of factories producing machinery and electrical equipments in these districts are established in the riverside towns. Other industries with nearly half or more of the units in these towns are chemical, printing, rubber, petroleum and coal products industries. Substantially large proportion of units in respect of many industries in Howrah and Hooghly districts are situated in the riverside areas. Nadia and 24 Parganas have large number of cotton and other textile units in the riverside towns. The miscellaneous group in the table includes industries like paper and paper products, leather and leather products, basic metals, non metallic mineral products, earthenware and various other products. The location of the units in the riverside areas should prove advantageous for any planning for river traffic.

TABLE—4

*Number and proportion of industrial units in the towns on Bhagirathi-Hooghly by district and by major group of industries**

Industry	Howrah	Hooghly	24 Parganas	Murshidabad	Nadia	Burdwan	Total	Total no. of units	
								Six districts	Calcutta
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Cotton textile	0.124	0.077	0.135	0.019	0.400	0 024	0.163	11628	330
	(81)	(294)	(183)	(18)	(1280)	(40)	(1896)		
Jute textile	0.548	0,892	0.534	0.600	0.118	0.333	0.620	234	21
	(34)	(66)	(39)	(3)	(2)	(1)	(145)		
Other textiles	0.393	0.498	0.413	0.136	0.226	0.037	0.342	6535	5170
	(622)	(267)	(1175)	(83)	(66)	(25)	(2238)		
Printing and Publishing	0.874	0.695	0.602	0.591	0.385	0.152	0.587	458	2431
	(104)	(41)	(71)	(26)	(15)	(12)	(269)		
Rubber, Petroleum & Coal Products	0.818	0 875	0.448	0	—	0	0.535	101	256
	(27)	(14)	(13)	(0)	(—)	(0)	(54)		
Machinery & Electrical Equipment	0.838	0.709	0.626	0.417	0.400	0.050	0.610	608	2075
	(145)	(39)	(174)	(5)	(4)	(4)	(371)		
Chemicals and Chemical products	0.827	0.656	0.350	0.250	0.292	0.048	0.495	546	1142
	(139)	(42)	(77)	(2)	(7)	(3)	(270)		
Miscellaneous	0.539	0.283	0.203	0.081	0.209	0.034	0.225	49086	21462
	(4392)	(1718)	(3336)	(590)	(762)	(257)	(11055)		

*Figures within brackets indicate no. of industrial units in the riverside towns.
Source : Census of India, 1961,
General Economic Tables, W. B. & Sikkim, Vol. XVI, Part 11, B (ii)

RIVER STEAMER SERVICE

The industrial complex by the riverside and the agricultural activities in the hinterland kept a large fleet of river crafts moving between Bengal, Bihar and Assam. The data for the organised traffic handled by the monopoly concern, the Joint Steamer Companies, formed in 1889, gives an indication of its size and the pattern.[2] There used to prevail a triangular pattern of traffic between the three States, determined by the type of commodities traded by them. Agricultural produce like sugar, rice, pulses and foodgrains, approximately weighing 50,000 to 60,000 maunds per month, were carried from Bihar to Assam by the Joint Steamer Companies, whose fleet consisted of nearly a thousand vessels of various types and sizes. In Assam the vessels were loaded with cargoes of jute, timber and tea for landing at Calcutta. The traffic from Calcutta to Bihar carried salt and manufactures like jute textiles, hessian and sacking, cotton textiles, construction materials, machineries and other products. The volume amounted to about 50,000 to 60,000 maunds per month. The trend of total volume of

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2. Ganga Traffic Survey, N.C.A.E.R., pp. 49-52 for an account of the river transport in the past

the river traffic on the Ganga borne by the steamer services between 1930 and 1956 is shown in table A2 in the Appendix. The table in the Appendix shows the total volume of trade between Bihar and the other two States operated by the Joint Steamer Companies. The volume of traffic continued to grow between 1930 and 1938, reaching from a level of 27 lakh maunds in 1930 to 74 lakh maunds per annum in 1938. Thereafter a slow process of decline set in, the downfall accelerating between 1942 and 1956. The traffic reached a low ebb at 16.7 lakh maunds in 1956. The Joint Steamer Companies wound up their activities by the end of 1957 because of the uneconomic returns from the operations.

The losses on the river services are ascribed to a large extent to the competitive alternatives offered by the railways and improvement in the road transport services. However, for lack of a detailed analysis of the economic and other factors involved in the operations of the Ganga steamer services it is difficult to reach definite conclusions about the causes responsible for the decline of the river transport system.[3] It would be instructive to compare the relative costs for providing alternative facilities for transport here. It is extimated that the cost of construction of new railway lines varies from Rs. 6 lakhs to Rs. 10 lakhs per mile. The maintenance cost per mile was about Rs 12,000 in the Eastern and about Rs. 17,000 in the North Eastern Railways in 1957-58. The cost of construction of roads would vary from a few thousands rupees to Rs. 3 lakhs or Rs. 4 lakhs depending on the type of road surfaces. The higher figures relate to the National Highways and include the costs of land acquisition and construction of bridges on the roads. The cost of maintenance of roads varies from Rs. 800 for major district roads to Rs. 8,600 for black top roads. In contrast to these the waterways, which are nature's gifts, cost only Rs. 350 per mile for maintenance.[4] Moreover, it is estimated that requirements of capital for river transport, both in absolute terms and in relation to the volume of business, would be less than that of the railways. It is also reported that in countries like Belgium, Holland and Germany' where routes are parallel to rail or road, and large units of goods are hauled over long distances, the steamer rates are less than rail or road routes. In some of the countries, however, the river transport rates have deliberately been pegged at a lower level than the railway rates so as to offset the disadvantage of slow movement by river The difference between actual costs and the rates fixed is subsidized by the State. How far the rates for river transport over the Bhagirathi-Hooghly stood in the way of its functioning in an economic manner is not clearly known. One of the critics however suggested that "if the Joint Steamer Companies had cared to modernise their fleet and streamline their operations, they might have been able to withstand rail/road competition better". (Srinivasan, 1969). We shall add our observations in this concern later. It is also on record that the Joint Steamer Companies did not avail 50 per cent of the traffic offerings, particularly on the Calcutta-Patna line.[5]

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[3] The following discussion on the transport economics is based on the facts and figures provided in the Ganga Traffic Survey.

[4] The capital cost for river route may not be small if it requires sizable expenditure on river training.

Difficulties in navigation due to deteriorating conditions of the river has been another major factor for the adverse turn of the Bhagirathi-Hooghly river system. Table 5 below shows the traffic for some of the sections handled by the Joint Steamer Services co-ordinated with railways by provision of through booking for the last few years of the concern.

TABLE—5

River traffic on the Ganga routes

(in tons)

Year	Routes		
	Calcutta-Ganga	Ganga-Assam	Ganga-internal
(1)	(2)	(3)	(4)
1951	49706	29843	914
1952	36395	22655	2015
1953	24418	18625	7060
1954	42600	44413	15325
1955	27942	34965	25969

Source : Ganga Traffic Survey, NCAER, p. 50.

The trend of the figures for the traffic on the Calcutta-Ganga stretch of the river contrasts sharply with those for the Ganga-Assam and Ganga-internal traffic. While the former was declining the latter was rising. Part of the loss in Calcutta traffic can of course be explained by the development of the rail and road traffic. It will however be difficult to isolate the issue of the river rates from the difficulties of navigation arising from the deficiency in the water level for the most part of the year. Irregularity in the services resulting thereby not only discouraged the regular customers from using the services but also affected the economics of operation of the river transport system itself. The traingular pattern of the river traffic between Bihar, Assam and Bengal came to be affected seriously by the gradual deterioration of the Ganga-Bhagirathi link. As one side in the triangle nearly snapped, the vessels so long operating over the total stretch found it difficult to balance their costs against the revenues from operations over the truncated routes. Other things like the generation of traffic, size of the fleet, etc, remaining same, the dislocation of the route could not but adversely affect the profitability of the enterprises engaged in the transport activities. The situation called for radical changes in the capital structure of the enterprises to enable them to offer a more economic fare structure to suit the changed situation. Concerns like the Joint Steamer Services had apparently not planned for such an eventuality and found themselves unequal to the occasion when it arose.

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[5] Ganga Traffic Survey, NCAER.

Another side of the triangle in the traffic pattern got dislocated in 1965 when hostilities broke out between India and Pakistan. This time the route to Assam from Bihar and West Bengal which lay through Pakistan was disrupted. Movement over the Ganga and the Bhagirathi-Hooghly gradually came to be localized principally within each of the three States. The connections between Bihar and Uttar Pradesh over the Ganga is not however considered here.

COUNTRY BOATS ON THE RIVER

With the winding up of the regular steamer services, the river traffic over the Bhagirathi-Hooghly is now borne mostly by the country boats. By our estimates based on the Survey by the Calcutta Metropolitan Planning Organisation (1967) the country boats in this region carry between 42 and 43 lakh maunds of goods annually. Most of the boats haul over distances between 20 and 50 miles. A large number plied over 10 to 15 miles. Relatively small number of boats and few launches covered distances over 100 miles.

The country boats have been a major means of water transport in the region. Indeed, the country boats in water transport has a role similar in significance to that of the bullock carts in over-land transport in India. The country boats provide employment and income to a sizable section of the population in the countryside. Previously the country boats were used to be manned by self-employed persons. The services offered sufficient returns for the maintenance and repair of the boats in addition to subsistence to the operators. With the decline in river traffic and rise in the general prices the individual boatmen were forced either to leave the profession or submit to the mahajan (moneylender) who came to own the boats. The boatmen are practically hired labour now. Usually 2 to 8 men are required for plying of boats with capacities for carrying loads from 100 maunds to 2000 maunds. Men in larger sized boats are required to be engaged in loading and unloading operations. Apart from the direct employment offered by the boat services, construction, repair and maintenance work for the boats call for a range of activities like carpentry, painting, wood work and supply of timbers over an extensive area.

The indirect effect of the river transport on employment would therefore be considerable. For short hauls of commodities of certain types the country boats have been holding their ground against the trucks and railways in much the same ways as the bullock carts on land. With the present rate of development in a labour surplus economy like India there are ample economic considerations for a spectrum of technology with varying degree of labour intensity to persist for a long period.

FISHING ACTIVITIES

Rivers have always been important for fishing in the Eastern region of India. The Bhagirathi-Hooghly was traditionally exploited for the catch of fish. With the incursion of salty sea water different varieties of sweet water fishes disappeared. There was a corresponding decline in the fishing activities over the river. However, as the demand for fish in the State has been continually rising, as may be seen through the rise in the prices for fish, other inland sources like ponds and lakes have been brought into use for pisciculture. The water from the river is also impounded in areas to form a lake for pisciculture. The overall effect has therefore been a net increase in the catch of fish. Figures in table 6 shows the catch of fish in the riverine areas in the recent years.

The figures of catch relate to the river regime extending upto 12 miles from the river banks. Data for the catch actually on the river are not separately available. The upward trend in the data noted lately has been occasioned more by the difficulties in supply from East Pakistan (Bangladesh) than for any internal factor. Table A3 in the Appendix provides the the estimates of fish catch in the other river systems and the sea around the state.

TABLE—6

Estimates of fish catch along the Bhagirathi-Hooghly and the price of fish at Calcutta.

Zone	Catch of fish (in tons)						
	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. 1. Nabadwip to Calcutta	465.3	399.6	360.4	659.7	609.7	500.6	640.8
2. Calcutta to Diamond Harbour	103.0	147.7	109.4	279.9	171.9	97.1	118.2
B. Index number of retail price of fish at Calcutta (Base : Nov. 1950=100)	104	104	120	122	116		

Source : (i) Annual Report of the Central Inland Fisheries Research Institute (ICAR),
(ii) Monthly Statistical Digest, West Bengal, March 1965.

FARAKKA BARRAGE PROJECT

We have discussed at length the serious repercussions of the failing supply of headwater into the Bhagirathi-Hooghly on the riverine activities. The suggestion for remedial measures to check the deterioration in the water supply dates as far back as 1858 when Sir Arthur Cotton pioneered the idea of a barrage across the Ganga at Rajmahal and stated that "if additional water were thrown into the Hooghly and kept flowing down it during the dry season, such an additional scour might just make the difference of preventing the Hooghly from silting up".[6]

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[6] The Farakka Barrage Project, Hydraulic Study Dept, Calcutta Port Commissioners.

Similar opinions continued to be aired by a string of renowned experts over another century before the ideas took roots with the Government of India which decided to implement in 1960 the Farakka barrage scheme drawn up by the technical experts. The project aims, with the help of a barrage on the Ganga at Farakka, a feeder canal and a cross regulator across the Bhagirathi, to discharge upto 40,000 cubic feet per second of water from the Ganga into the Bhagirathi. This, together with the usual discharges from the Ganga during the monsoons should be adequate to restore the hydraulic balance of the tides in the Hooghly. The project is expected to be completed by 1970-71.

The restoration of headwater supply to the Bhagirathi-Hooghly is going to affect not only the riverine activities in a positive manner but also the overall economy of the State. It is difficult to assess fully the significance of an entirely new situation that is going to arise out of this. For over 300 years the maximum number of days the connection between the Ganga and the Bhagirathi remained effective in a year has been declining continuously to reach the present position of around 60 days a year. Establishment of the connection between the two river systems throughout the year cannot but have far reaching consequences on the riverine economy.

GROWTH OF THE CALCUTTA PORT

The main objective of the Farakka Barrage Project has been to check the deterioration in the navigability in the Port of Calcutta and river regime of the Bhagirathi-Hooghly river. The Port would be by far the biggest beneficiary from the implementation of the project. By increasing the velocities of the seaward currents during the months outside the monsoon period, the present process of choking of the channels by upward sand movement will not only be arrested but the trend is expected to be reversed over years. Suitable river training works will gradually reduce the severity of bore tides thereby increasing the berthing capacity of the Port and the drafts of ships at the riverside berths and moorings. This will imply a rise in the capacity of the Port to accommodate larger number of ships with higher gross tonnage than before. It will be possibie to make a breakthrough in the present stagnation in the level of Port activities.

In the absence of a detailed analysis it is not possible to quantify the impact of the growth of the Port activities on the regional economy. Some impressions of the same can however be had from the figures relating to the size of employment generated by the Port activities.

The Port Commissioners are the biggest employers of labour in the region. Mukherjee, (1968) reported the results of a survey conducted by the Port Commissioners in 1961. The survey showed that about 42,000 people were on the direct pay roll of the Port Commissioners and another 19,000 workers registered and listed with the Dock Labour Board. Indirectly, 171,5C0 men were working in depots, sheds, warehouses and other establishments. The Stevedores and their employees numbered 3,400. 48 steamer agents employed about 4,803 men and 117 clearing agents accounted for nearly 6,000. There were 16,000 truck drivers, cleaners and attendants attached to 4,000 trucks running with Port Commissioners' permits. This, along with other workers add up to approximately 400,000 persons directly or indirectly engaged in Port activities. The figure does not include persons engaged in banking, commerce and trade activities dependent on the Port traffic. It is estimated that the workers, directly or indirectly engaged in the Port activities along with their families would number about 1.8 million. Taking the total volume of cargo handled by the Port in 1960-61 into consideration, we can see that 400,000 workers were engaged, directly or indirectly, in handling 9.5 million tonnes of cargo in 1961. Dr. Bhatia (1969) expects the Calcutta-Haldia Port traffic to reach the figure of 45 millon tonnes in 1985. One would not be surprised to find the employment figure multiplying 2 to 3 times the present level in such an eventuality. The figure could be higher still because of the constructions required in the new township.

PROSPECT OF MECHANIZED RIVER TRANSPORT

The perennial supply of water with adequate depth will permit navigability of the river by vessels of different sizes. It will be possible to organize the river transport system on a regular basis. The revived system will provide regular employment to persons in number several times more than as at present. Obtaining a direct route from Calcutta to upper India it will be possible to reduce the distance between Calcutta and some of the river stations compared to their distance over land routes.

It is expected that regular services will make the mechanized transport system over the river economically viable (Srinivasan, 1969). Drawing upon the exepriences of the Central Inland Water Transport Corporation, Srinivasan estimated that the cost of operations for a fleet of a tug with 500 h.p. machine and four barges with a pay-load of 100 tonnes each, plying between Calcutta and Allahabad, would vary between 3.5 paise to 8.73 paise per tonne kilometre depending on the intensity of traffic. The costs compare favourably with the railway and the road-rates for upward stations from Calcutta. The railway rates range from 3.0 paise to 31.8 paise per tonne kilometre for various commodities. The corresponding road rates are between 13.3 to 17.2 paise. The detailed figures are given in Appendix Table A4.

Whether the river transport system would be competitive or not in relation to the railways and the road transport will remain to be tested in actual practice. However, certain complementary characteristics of the river traffic can perhaps be easily appreciated. A number of rail-heads is located within the easy reach of the Bhagirathi-Hooghly. There are three bridges across the Bhagirathi-Hooghly now. All these points can be used to co-ordinate traffic between rail and river. Such a co-ordination between the boats and the rail and road traffic is already there to a limited extent. With the opening of river traffic in a bigger way it would be necessary to provide adequate facilities for landing and interchange facilities for the freights. When completed, Farakka Barrage site will provide another important point for such interchanges. It should be possible to transfer different kinds of goods from ships' holds on to the barges which would take them directly to the railheads at Farakka for overland journey. For bulk delivery of goods and for certain types of heavy machinery and equipment, which cannot conveniently go by rail or road, river transport would prove more convenient. Also, exportable tea from Assam and North Bengal may be moved by rail or road to Farakka and from there to the Port by river for direct loading into the ship's hold.

The need for drawing up plans for developing navigation in the rivers in an integrated manner with the overall transport system in the region through which the rivers flow was recognised by the Committee on Transport Policy and Coordination set up by the Planning Commission (1966). An appropriate structure of freight rates for the rail and the river rates can be worked out in such a way that the goods in short haul are encouraged to take to the river routes releasing railway space for more of goods in long haul. In an expanding economy the increase in the volume of traffic can be diverted rationally without affecting seriously the current levels of operations in the different branches.

There is also the scope of organizing passenger services by steamers at different points along the river. A number of services, including ferry services for passengers is already there. The river services would offer an attractive opportunity for promotion of tourism too.

REVIVAL OF COUNTRY BOAT TRAFFIC

As for the country boats it is quite clear that their numbers will multiply particularly in respect of the freights in the short haul and those engaged in carrying goods over the canals and tributaries connected with the Bhagirathi-Hooghly. We noted before how the country boats survived the ordeals of nature. It is only to be expected that they will fare better with improvement in the river condition. As many of the canals and rivers connected with the Bhagirathi-Hooghly become revitalized through the increased flow of water in the river system areas inside the State hitherto inaccessible to markets get opened up. The country boats will remain for long the chief means of transport in these channels. The scope of operations by the country boats will therefore widen. Considering the employment potential of the country boat system, it will be advisable to plan for easy credit facilities to the intending operators when Farakka Barrage is completed.

OTHER BENEFITS FROM FARAKKA PROJECT

Operations on the costly DVC canal should be economically feasible when the Farakka Barrage is completed. The canal emerging from near the Durgapur Barrage, connects the river Kunti and joins the Hooghly at Kuntighat, 56 kilometres upstream from Calcutta, after traversing a distance of 136 kilometres.

It was planned that the powered crafts engaged for transport on the canal would carry coal, paddy, construction material and finished products from the Durgapur Steel Plant and take back colliery stores and other goods. Operations on the canal in 1965 were however found to be uneconomic because of the heavy dependence of the traffic on coal movements. Movement of coal on road and railways were found much cheaper. The canal has been closed since. With the diversification in the foreign export of the economy, it should be possible to plan in terms of more of engineering materials from Durgapur for the canal traffic. With assured regularity of the services over the Hooghly more customers would be found for transport of goods from Calcutta end as well.

There will be a fillip to the fishing activities through the flow of sweet waters in the river. With the prevailing trend in the prices of fish in the State more people will be interested to join the trade. The fishing activity over the river has dwindled to an insignificant level. The Central Inland Fisheries Research Institute found only 1486 boats engaged in fishing over the river in 1959-60.

WATER AND DRAINAGE FOR CALCUTTA

The Calcutta city and its environ stand to benefit in a large measure through the regeneration of the river. The rise in the bed of the Hooghly through cumulative deposit of sand has been causing serious impediment in the drainage of city waters through the outfall systems, comprising of a number of canals and rivers flowing into the Hooghly. Clearing of the river bed will lead to the decongestion of the drainage channels and free the city and other adjacent municipalities from the health hazards persisting so far.

The salinity of the river water has been aggravating the problem of drinking water supply to the city. The increase in the salinity of the river has forced the civic authorities to write off the surface water as a source of additional water supply for the city. Costlier measures for tapping the underground water is now in vogue in the city. Nevertheless the imbalance between the demand and supply of drinking water persists. The Farakka Barrage Project will go a long way to quench the thirst of millions in the city and the adjacent municipalities.

The Farakka Barrage Project thus holds out great hopes for the revival of economic activities on the Bhagirathi-Hooghly river system.

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APPENDIX

TABLE—A1.

Riverside towns with population and working population by districts

Name of the Towns	1961		Name of the Towns	1961	
	Population	Working Population		Population	Working Population
(1)	(2)	(3)	(1)	(2)	(3)
District : Hooghly			District : Howrah		
1. Hooghly-Chinsura	83104	21865	1. Bally	130896	55051
2. Bansbaria	45463	16962	2. Howrah	512598	189517
3. Chandannagar	67105	18911	3. Sankrail	11844	4338
4. Bhadreshwar	35489	13643	4. Sarenga	10704	3362
5. Champdani	42129	16574	5. Manikpur	7844	3019
6. Serampore	91521	32242	6. Jhorhat	6438	1652
7. Rishra	38535	16628	7. Banupur	5654	3093
8. Konnagar	29443	10732	8. Bauria	8492	2224
9. Kotrang	31031	9410	9. Fort-Gloster	13785	7145
10. Uttarpara	21132	6653	10. Chengail	14831	6331
11. Baidyabati	44312	12424	11. Uluberia	18509	6030
Total	569264	176044	Total	741595	281762
District : Murshidabad			District : Nadia		
1. Jangipur	24201	6599	1. Nabadwip	72861	20477
2. Jiaganj-Azimganj	23675	6430	2. Chakdaha	35089	7233
3. Murshidabad	16990	2979	3. Kalyani	4616	1797
4. Beldanga	7841	1834	4. Santipur	51190	13009
5. Berhampore	62317	15970	5. Phulia	3813	1074
Total	135024	33812	Total	167569	43590

Table—A1. (Contd)

Name of the Towns	1961 Population	1961 Working Population
(1)	(2)	(3)
District : 24 Parganas		
1. Kanchrapara	68966	19356
2. Halisahar	51423	18201
3. Naihati	58457	20008
4. Deulpara	17797	4612
5. Bhatpara	1476 0	56050
6. Ichapur Defence Estate (NM)	12382	4782
7. Garulia	29041	10869
8. North Barrackpur	56683	16836
9. Barrackpur Cantt.	16912	5869
10. Titagar	76429	35526
11. Barrackpur	63778	21079
12. Panihati	93749	27953
13. Khardaha	28362	7846
14. Baranagar	107837	32948
15. Kamarhati	125457	44896
16. Garden Reach	130770	47079
17. Batanagar	9664	4505
18. Nangi	30992	7537
19. Budge Budge	39824	15231
20. Birlapur	11601	4981
21. Diamond Harbour	10135	2549
Total	1187889	408713

Name of the Towns	1961 Population	1961 Working Population
(1)	(2)	(3)
District : Burdwan		
1. Dainhat	10519	2739
2. Kalna	22603	6139
3. Katwa	20621	5617
Total	53743	14495
Total urban population in all the 6 districts in West Bengal	2855084	958416
Calcutta	2927289	1182789
Total urban population in all the 6 districts and Calcutta	5782373	2141205

Source : Economic Tables, 1961 Census,
West Bengal and Sikkim, Table B (ii)

TABLE—A2

Traffic Export and Import figures of Bihar account of Ganges Steamer Services (including feeders) from 1930-1956.

(Maunds)

Year (1)	Export (2)	Import (3)	Total (4)
1930	2032112	673632	2705754
1931	2091652	918800	3010451
1932	2139202	1258992	3398194
1933	3252931	1589729	4842660
1934	2466100	2175200	4641300
1935	2575719	2173219	4748988
1936	3992501	2267511	6260012
1937	3334845	2509345	5844190
1938	4938650	2493510	7432160
1939	2963811	2739111	5702922
1940	3360300	2887500	6247800
1941	3779833	1512333	5292166
1942	2705503	1789113	4494616
1943	2424558	1364302	3788860
1944	1228800	1067000	2295800
1945	1127730	1163303	2291033
1946	1131144	1384802	2515946
1947	1628973	2240207	3869180
1948	1269605	1115403	2385008
1949	1261700	828500	2090200
1950	622412	533012	1155424
1951	1025577	1293303	2318880
1952	925401	989314	1914715
1953	840930	848300	1689230
1954	1560489	1265970	2826459
1955	1829056	1537941	3366997
1956	971459	694501	1665960

Source : Ganga Traffic Survey—NCAER, page 67.

TABLE—A3

Zonewise estimates of fish catch (in tonnes) in some rivers of West Bengal

Zone	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67 Mar '66 to Feb. '67	1967-68 Dec. '67 to Nov. '68
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
I Nabadwip to Calcutta	465,3	399.6	360.4	659.7	609.7	500.6	610.8	773.3	838.1
II Calcutta to Diamond Harbour	103.0	147.7	109.4	279.9	171.9	97.1	118.2	136.1	316.8
III Lower Sundarbans including Digha	3128.1	2566.2	3237.8*	3872.2	5341.2	9491.5	5289.9	5308.0	5823.4
IV Rupnarayan	349.7	558.5	367.9	269.2	168.1	165.4	282.1	383.0	957,4
V Port Canning	102.5	99.9	81.4	79.9	120.8	158.9	215.1	161.9	118.3
Total	4138.6	3771.9	4156.9*	5160.9	6411.7	10413.5	6516.1	6766.3	8054.0

* Raidighi data for February are not included.

Source : Annual Reports of Central Inland Fisheries Research Institute (ICAR)

TABLE—A4

Costs of movement in paise/ton kilometre by rail and road of specified commodities on selected sections (1962-63)

Sections	Distance (kms)	Name of commodity	Rail wagon loads	Rail smalls	Road
(1)	(2)	(3)	(4)	(5)	(6)
1. Howrah-Nagpur	1131	Building materials	3.0	4.1	13.3
2. Howrah-Varanasi	678	Iron & Steel	3.7	7.7	13.8
		Mineral oils	4.3	9.5	
3. Calcutta-Kharagpur	116	Tea	14.7	21.3	17.2
4. Calcutta-Burdwan	107	Jute manufactured	14.5	31.8	17.1

Source : Calculations based on Table 4, p. 29. Committee on Transport Policy & Coordination Final Report, January, 1966. Planning Commission, Government of India.

REFERENCES

Batra, P. N. (1968) : *Introduction to the problems of navigation in the river Hooghly*, India in Industries Vol. IX, No 1, pp. 33-36.

Bhatia, V. G, (1969) : *Future of traffic and trade Calcutta/Haldia*, in Symposium on Future of the Port of Calcutta, pp. 29-35. Inst. of Port Management, Calcutta.

Bhattacharya, S. K (1969) : *Seaway to Calcutta and Haldia*, in Symposium on Future of the Port of Calcutta, pp. 24-28. Inst. of Port Management, Calcutta.

Central Inland Fisheries Research Institute (ICAR) : *Annual Reports*, Central Inland Fisheries Research Institute, Barrackpore, West Bengal.

Census of India, (1961) : *District Census Handbooks*. Govt. of India.

— *General Economic Tables, W. B & Sikkim*, Vol. XVI, Part II, B (ii).

Hydraulic Study Dept., Calcutta Port Commissioners (1967) : *Project for the Preservation of the Port of Calcutta—The Farakka Barrage Project*, Feb. 1967, Port Commissioners, Calcutta.

Institute of Port Management (1969) : *Symposium on Future of the Port of Calcutta*, 3rd May, 1969. Institute of Port Management, Calcutta.

Maass, Arthur & Others (1962) : *Design of Water-Resource Systems*. Macmillan & Co. Ltd.

Mukherjee, N. (1968) : *The Port of Calcutta—A Short History*. The Commissioners for the Port of Calcutta, pp. 208, 232.

National Council of Applied Economic Research (1960) : *Ganga Traffic Survey*, N.C.A.E.R., New Delhi.

Planning Commission, Govt. of India (1966) : *Final Report*, Committee on Transport Policy and Coordination, January, 1966.

The Regional Planning Wing, C. M. P. O., (1967) : *West Bengal Transport Survey Report on Inland Waterways*. Govt. of West Bengal.

Roy, R. (1969) : *The Port of Calcutta—a glimpse into the future*, in Symposium on Future of the Port of Calcutta, pp 36-41. Inst. of Port Management, Calcutta.

Sengupta, P. (editor) (1968) : *India in Industries*, Vol. IX, No. 1, Indian Market Research Bureau, Calcutta.

Srinivasan, K. (1969) : *Inland water transport to and from Port of Calcutta Bhagirathi-Hooghly-Ganga system*, in Symposium on Future of the Port of Calcutta, pp. 4-11, Inst. of Port Management, Calcutta.

AGRICULTURE IN BHAGIRATHI-HOOGHLY BASIN (IN WEST BENGAL) : PROGRESS & PROSPECTS

G. K. DUTT

Abstract

The Bhagirathi-Hooghly basin within West Bengal being one of the most fertile and densely populated parts of the country, had been under cultivation since the very early times. Paddy, particularly *aman* paddy, predominated as a monocrop. Methods of farming were primitive, consequently the yield rate was low.

Aman paddy, because of its peculiar growth period, leaves no room for a second crop on the land producing *aman* paddy. *Aus* paddy on the other hand is more accommodating in this respect. Unfortunately, this crop is not favoured since it is condemned, mostly out of prejudice, as a crop of low grade and poor yield. Double cropping is, therefore, not much prevalent.

For modernising the agricultural practices and the agricultural output it is necessary to make available more and more land for double cropping which is possible by increasing the area under *aus* paddy. It is quite obvious that a major break through is to be made by planned and sustained efforts and such efforts should primarily be directed towards raising the yield rates in all varieties of paddy and if for once it could be established and the common farmer made to believe that *aus* crop can be as good as *aman* crop the entire farming practice could be changed and reset on a rational basis.

The progress made during the last ten years regarding use of high yielding varieties of seed, experiments carried with such seeds and their results, use of fertilizers, popularity of agricultural implements, irrigation facilities etc. have been reviewed. The change noticed in the matter of increasing popularity of *Rabi* crops, e.g. wheat and potato, has been analysed. The role played by the government machinery and cooperative societies in modernizing agriculture has been recognised. Farming practices that would suit the conditions of the land and people in this part of the country have been suggested.

Among the states in India West Bengal belongs to the category of small States, with its total area of 87,676 sq. km. i.e. a little less than 3 per cent of India's land areas. It stands thirteenth if the States are ranked on the basis of their land areas. In this land live about 41.4 million people (estimates for 1967) and more than 50 per cent of the labour force that is available out of them is engaged in agricultural operations of one form or the other. Agriculture is therefore, the leading occupation in the State, and by inference in the Bhagirathi-Hooghly basin lying within it.

PATTERN OF LAND UTILIZATION

The available statistics on landuse in West Bengal and the Bhagirathi-Hooghly Basin within West Bengal, given below would reveal that already about 60 per cent of the total land of the State is under the plough. This is a fairly high percentage in comparison to the other States in India as well as other countries of the world. High pressure of population, the nature of the available terrain and other natural conditions favourable for agriculture have led to such a high percentage of crop land in the State.

TABLE—1

Land Utilization Statistics 1962-63

(in .000 Hectares)

Total area	Forests	Land not available for cultivation	Uncultivated Land (Excluding current fallows)	Current fallows	Net area sown
8852 (6877.2)	1102 (836.2)	1293 (969.2)	639 (484.9)	382 (313.6)	5436 (4073.3)

Sources : Statistical Abstract : West Bengal 1962

Figures in brackets indicate the area within the Bhagirathi-Hooghly Basin.

On the basis of the Table-1 it is calculated that the net area sown per head of agricultural population is only about 0.32 hectare as compared to 0.72 hectare in India as a whole. The shortage of available land, however, has not been matched with the necessary intensive use of the same. Double cropping or multiple cropping till recently (1962-63) covered 16 per cent of the net area sown.

Among the districts of West Bengal lying within the basin the highest percentage of land under cultivation is in, Birbhum 73 per cent, followed by Nadia 71.5 per and Murshidabad 70.3 per cent. In respect of double cropping, Nadia (52 per cent) and Murshidabad (43 per cent) lead the rest of the districts. For other districts this rate varies from 6 per cent to 22 per cent.

Cropping pattern

Paddy is the most important crop raised in West Bengal and it covers on an average more than 70 per cent of the area under cultivation. Together with items of food crops (i.e. grams, pulses, and wheat etc.) it accounts for 80 per cent of the total cropped area. In paddy cultivation the *aman* variety (winter or *Haimantic* paddy) predominates, so much so that in 1961-62 *aman* covered 88 per cent of the total area under paddy. There are no distinct crop-regions due to the predominance of paddy cultivation all over the State. Nevertheless, the detailed crop distribution in the basin shows some degree of specialization. Pulses are concentrated in Murshidabad and Nadia districts ; jute in the Hooghly basin and also in the post-partition introductions in the suitable lands beyond the basin. Murshidabad and Nadia have a sizable proportion of land under oil seeds. As will be discussed in detail later, the land on which *aman* paddy is grown, leaves no scope for a second winter crop, consequently in the major part of the State winter cultivation (popularly known as *rabi*) common in other parts of the country, is not normally practised. Rice eating habits of the people also played its part in creating reluctance in the local farmers in growing any cereal other than paddy. Thus, in comparison to paddy, wheat covered only 1 per cent of the total cropped area and the hectareage under other cereals e.g. maize, millets, barley etc. is very small. During the last decade, on an average, oil seeds in the State were grown on 131,000 hectares. Other important crops grown in the basin within West Bengal are sugarcane, jute, potatoes and pulses. Jute was cultivated on 456,000 hectares and sugarcane was planted in 41,000 hectares. Potato is gaining importance and the State of West Bengal has gradually become an important producer of the commodity ; in 1964-65 the crop was sown in 69,000 hectares producing 786,000 tonnes.

Yield pattern

The yield rates of the major crops are generally higher in West Bengal than in India as a whole. However, these rates do not compare favourably with those in many other States. Thus, for example in 1964-65 yield of rice in the State was 1233 kg./hectare as against 1926 kg. in Goa, 1595 kg. in Madras, 1550 kg. in Mysore and 1381 kg. in Kerala. In case of jute the yield rate was better, it being 1437 kg./hectare, next only to U.P. (1569 kg /hectare). The yield rate of potato (11,391 kg./hectare) compared favourably with that of the other States, although it was much below the highest rate of 15,222 kg. per hectare recorded in Punjab. In case of sugarcane the yield rate is very much on the lower side, 4667 kg. as compared to 9593 kg./hectare in Madras, 8680 kg./hectare in Andhra Pradesh, 8610 kg./hectare in Mysore and 8093 kg./hectare in Maharashtra. The yield of such minor crops as oil seeds, jower, tobacco etc. are also below the national average.

IRRIGATION PATTERN

With the rather seasonal nature of rainfall that the basin receives, and its wide variations both in respect of period and quantity, irrigation in some form or other to augment the supply is essential for cultivation in the State. The entire agricultural operation is tuned up with the onset of monsoon which forms the foundation as it were of the agricultural operation. Planting of *aman* paddy, by far the most important crop of the State, is dependent on it, standing crops like jute and *aus* paddy thrive on it. But the rainfall is rarely regular. It may be in time, early or late and it may as well be excessive, adequate or scanty. The fact that a year of bumper crop production is invariably connected with a timely and adequate rainfall in that particular year indicates the dependance of agriculture on rainfall. Variations in rainfall within the basin is not uncommon, thus while some districts such as Midnapur, in a particular year may have excessive rains leading to floods, districts like Bankura and Purulia in the western border of the State of West Bengal, suffer prolonged drought.

If irrigation is to play its significant role in the agricultural performance of this part of the basin this should be planned so that control of flood and supply of water exist side by side.

Flood control is one of the chief objectives of the various River Valley Projects that have been taken up during the plan periods. Thus, devastating and widespread floods of the River Damodar have been controlled to a great extent. The Kangsabati Project in Midnapore, now nearing completion, has brought an end to the nearly regular occurrence of flood in the district. If water is to be made available to the fields when the adequate supply from rainfall is not forthcoming, the State has to look forward to artificial irrigation by exploiting rivers, canals, tanks and sub-surface water. The districts situated in the western border of West Bengal viz. Purulia and Bankura etc., have lower water table and relatively insufficient rainfall and as such badly need irrigation facilities.

In 1958-59 the gross area irrigated from all sources in West Bengal was 1,351,246 hectares (23 per cent of net area sown) of which 777,806 hectares (57.56 per cent) were irrigated by canals (government and private), 36,422 hectares (27.25 per cent) by tanks, 15,783 hectares (1.17 per cent) by wells and 189,393 hectares (14 02 per cent) by other sources.

Irrigation from government canals is mostly found in Burdwan, Birbhum and Midnapore districts lying in the Basin, while irrigation from private canals is carried out largely in Midnapore. In the relatively dry districts of Bankura and Birbhum irrigation by tanks predominates than irrigation by wells.

Midnapore claims the largest irrigated area in West Bengal and together with Burdwan, Bankura and Birbhum accounts for 68 per cent of the total area under irrigation. Among the irrigated crops rice together with other cereal crops account for 99 per cent of the total irrigated area of which rice alone covers 90 per cent. Even though rice lands get a lion's share, as it were, of the irrigation facilities, only 23 per cent of the rice growing areas are irrigated. Sugarcane needs frequent supply of water for successful cultivation, only 45 per cent of the area under sugarcane has facilities for irrigation.

As a district, Nadia has the smallest irrigated area.

RABI CROPS VIS-A-VIS KHARIF CROPS :

As mentioned earlier the farming pattern in West Bengal has its own peculiarities. Paddy, particularly *aman* paddy holds a predominant position among the crops grown and because of its rather inconvenient growing season covering a part both of the *kharif* and *rabi* seasons, it nullifies the scope of growing another crop on lands on which the *aman* is grown. Therefore the production of *rabi* crops which is insignificant in comparsion to other crops, remained more or less static.

On a closer examination it will be observed that it is only the *kharif* crop which can afford to accommodate a second crop on the same land during *rabi* seasons. The scope of cultivation of the *rabi* crops is necessarily limited to the land on which *kharif* crops e.g. *aus* and jute are cultivated. It may be inferred from the land utilization data available for the Basin that "area sown more than once" as indicated in the tables are the areas that support both *rabi* and *kharif* crops in a year. These figures compare very favourably with the total area under *aus* paddy and jute, suggesting thereby that over 90 per cent of the land put to those two crops are utilized for growing a second crop in the *rabi* season.

TABLE—2

Percentage of area sown more than once to the total area under aus *Rice and Jute*

(Area in '000 hectares)

	1948-49	49-50	50-51	51-52	52-53	53-54	54-55	55-56	56-57	57-58
1. Total area under *aus* and Jute	629	722	718	827	881	852	727	840	785	853
2. Area sown more than once	541	522	609	662	771	814	763	838	821	771
% of 2 to 1 above	86	73	85	80	88	96	105	100	105	90

Obviously unless more area are put under the *aus* crop not much land would be released for *rabi* crop. As the Table above reveals, the land available for double cropping is being fully utilized for growing a second crop, so if double cropping area is to be increased, land for it must be made available in the first place.

Actual conditions existing at present are, however, far from ideal. The Table-3 would indicate that on an average 88 per cent of the paddy land is given over to *aman* paddy. This overwhelmingly large area covered by *aman* restricts further utilization of the land and is therefore virtually a monocrop area.

The State has to restrict largescale growing of *aman* paddy and release considerable acreage to *aus* and its complementary *rabi* crops ; because as stated earlier, scope for double cropping can be had only on fields growing *aus* or *kharif* crop. This is agrnomically feasible, as much of the area with light textured soil now put to *aman* is unsuitable for *aman*, which is testfied by the poor *aman* harvest in many districts and sub-regions of the Basin within West Bengal. These lands are, on the other hand, ideal for transplanted *aus* which is high yielding and contrary to the existing belief not necessarily coarse grained.

It is quite apparent that the present

crop pattern has not resulted from scientific landuse planning based on soil-crop-water complex but is the product of individual peasant's choice.

In the absence of any efforts for developing agriculture either by the government or by the landlords, dependence on single cropping impoverished the widely practised traditional agriculture.

TABLE—3

Area under aman & aus *in West Bengal*

(in '000 Hectare)

	52-53	53-54	54-55	55-56	56-57	57-58	64-65
Area under Aus	549	635	505	524	513	546	612
Percentage	13	15	15	1	13	12	13.1
Area under Aman	3562	3615	3458	3568	3541	3580	4037
Percentage	87	85	85	87	87	88	86.4
Area under Boro	—	—	—	—	—	—	22
Percentage	—	—	—	—	—	—	0.5
Total land under rice	4111	4250	3962	4092	4054	4396	4671

Source : Statistical Abstract—West Bengal, 1961

NEW OUTLOOK

It is quite obvious that a major breakthrough was to be made by planned and sustained efforts and such efforts should primarily be directed towards raising the yield rates in all varieties of paddy and if for once it could be established and the common farmer made to believe that *aus* crop can also be as good as *aman* crop, the entire farming practice could be changed and reset on a rational and scientific basis.

Fortunately, the agricultural departments both at the central and state levels are conscious about the matter and all our efforts are being made in that direction.

In West Bengal the first step was to find a high yielding quick growing strain of paddy suitable under the condition of soil, climate and rainfall of the region

The Indian Agricultural Research Institute and in particular the Rice Research Institute at Cuttack did some valuable work in that direction and several hybrid varieties were developed.

The International Rice Research Institute at Manila (Phillipines) has done most outstanding work in that direction. The scientists there had cross-bred the different varieties of paddy that are grown in parts of tropical Asia and have evolved IR-8 that has given outstanding production in every Asian country. In the same Institute, a strain of paddy evolved by cross-breeding of two local varieties of Taiwan is perhaps the most valuable contribution in the field of rice farming. This variety, popularly known as Taichung Native-I, when given adequate amount of fertilizer and water, far exceeds all other strains of paddy evolved recently in the matter of per hectare yield.

Introduction of this variety in West

Bengal has brought a revolution, as it were, in rice cultivation and farming practices in this State. On experimental farms this variety has recorded an yield of 6000-8000 kg./hectare as compared to 3000-4000 kg /hectare produced by local varieties. There are several factors that have made the Taichung Native paddy particularly suitable for cultivation in West Bengal (and within the Basin also).

Modern research in paddy cultivation has established that agro-climatic factors play a dominant role in rice production. Duration of sunlight in particular, play a very significant role in increasing the yield. The Taichung Native Plant, with short stature, erect dark green leaves and strong non-lodging straw can utilize to the optimum, available sunlight for their photo-synthetic activity. If adequate water is available, it can be grown in any season so that Taichung under suitable condition can be grown as *aus*, *aman* or *boro* crop. The fact that it attains maturity within 120 days makes it all the more acceptable. It responds very well to nitrogenous fertilizers and with greater utilization of irrigation water, two or even three crops of rice can be raised from the same plot of land.

Taiwan and West Bengal being located in similar latitudinal zones have more or less comparative agro-climatic conditions. Both have more fairly heavy monsoonal rainfall, similar range of temperature, similar average duration of insolation per day throughout the the year and even similar soil conditions of the fields where paddy is grown (alluvial soil in both the cases). All these have helped the Taichung Native-I to adapt itself very well to the farms of West Bengal and it has established itself as the most successful variety of paddy ever grown in this land. In co-operative trials carried out at the Jute Research Institute, Barrackpore, it has been seen that the Taichung Native can be fitted in sequence with jute. When transplanted on 25 August and 9 September, Taichung Native could be harvested by the second or third week of November, leaving scope for sowing *rabi* crops like wheat etc. in November-March. In similar rotational trials carried out in cultivator's fields near Cuttack, jute was harvested in August and the field transplanted with Taichung Native-I was harvested on 22 November which gave an yield of 5,128 kg./hectare. The need to popularise this rotation in all jute growing areas is obvious.

The Taichung Native-I paddy has shown itself capable of standing upto drought conditions in some areas. It has given considerably better yields, than the traditional varieties Field studies had indicated that these Taiwan varieties were more drought resistant than the other high yielding Japonica types

In a trial to find out the best time of planting for the second rice-crop, Taichung Native-I was planted on 25 December, 1966, with 100 kg. nitrogen/hectare and a net yield of 5000 kg /hectare was obtained. This indicates that Taichung Native I could form a very good *aman* crop in rotation.

The Central Rice Research Institute reports that during *kharif* season, another Taiwan variety IR-8 has given the highest yield in varietal and fertilizer trials, and also in bulk multiplication plots. In the fertilizer-trials it gave an average yield of 6151 kg./hectare under 50 kg. nitrogen/hectare and 7500 kg./hectare under 100 kg. of nitrogen level. In multiplication plots it has also given 6600 kg./hectare. During the *rabi* season it was the most outstanding variety in the collections giving about 7000 kg./hectare in bulk plots. In germination studies, seeds of IR-8 were dormant at harvest stage (i.e. 30 days after flowering) and the dormancy period extended upto 8-10 days from harvest. This character is a valuable attribute in early maturing variety which often gets caught by late rains in the grain maturing stage. Studies in cooking qualities of IR-8 have indicated that it has low alkali disintegration temperature, high water absorption and sedimentation value, and nearly 4.2 times volume expansion indicating fairly good cooking quality.

The greatest snag with the above two varieties is their susceptibility to attack by pests. Insecticides sprayed and dusted in time counteracts this menace successfully but a section of the local farmers are not keen on playing about with poisonous insecticides. With this point in view the Rice Research Institute has developed two new varieties *Jaya* and *Padma* through crossing Taichung Native-I with an Indian strain. In the *kharif* season of 1969, the State would use for the first time the *Padma* variety of high yielding paddy seed. It is expected that about 50,000 hectares will be covered under this particular variety. About 10,000 quintals of *Padma* seeds have been sent to the State from the Centre. This variety which was released in December 1969, has finer grains and it matures faster. The National Seeds Corporation experimented with this variety in late 1968 at Vijaywada for seed multiplication, which turned out sufficient seed for about 150,000 hectares of *kharif*

The cultivation of *boro* paddy neglected so far because of the poor yield and quality of the produce has now drawn attention of the Agricultural Department and efforts are being made to make use of the lowlying areas for improved *boro* (winter) cultivation. In the district of Midnapore about 50,000 hectares of *boro* paddy was transplanted in the winter of 1968. The irrigation problem was partly solved by sinking of deep and shallow tube wells and by the construction of *boro bundhs*. More than 70 per cent of this has been put under IR-8 or Taichung Native-I. The authorities now expect that even on a modest scale about 100,000 tonnes of rice would be available from the *boro* fields.

As stated earlier, this has, in fact, given the starting point and new life to the efforts of the Agricultural Extention Officers in educating the farmers in the modern methods of farming, namely, use of fertilizers, simple mechanical agricultural implements, use of insecticides, etc. To grow Taichung or IR-8 paddy successfully one must have to use the right type and quantity of fertilizers in the appropriate times, use insecticides at various stages and in various forms e.g. spraying, dusting etc. and arrange for water in sufficient quantity. Since the result in the form of a harvest of bumper crop that invariably comes after putting so much of labour and costs, this is getting increasingly popular among all rice farmers. It has been established, thanks to the efforts of Agricultural Extension Officers and other workers in the field, that output of paddy under modern methods of, cultivation is undoubtedly rewarding.

The modified rice cropping patterns and the introduction of high yielding varieties of paddy requiring short growing period will in effect provide a continuous harvest of rice in the Basin. This will, undoubtedly, have a stabilising effect on the present price level of rice in West Bengal as a whole. So far *aman* which was the main rice crop, was harvested during the period from November to January. This suited long storage by hoarders, enabling them to create an artificial scarcity and increase prices. Cropping intensity of two crops of rice from the same field in a year will increase with the minor irrigation schemes taken up on a very large scale by the Directorate of Agriculture. The schemes which include shallow tube wells, pumping sets and river-lift irrigation have been very popular with the farmers.

THE ROLE OF THE GOVERNMENT MACHINERY

Several programmes e.g. Intensive Agricultural Districts Programme, Intensive Agricultural Areas Programme and High Yielding Varieties Programme have been introduced by the Agricultural Department of the Union Government in recent years with a view to popularise the latest methods of growing and marketing the new strains of all crops. Regional conferences are held periodically to review the progress made and to find solutions for problems faced.

One must give credit to the organisation set up by the State Government to propagate the new methods to each and every farmer of the State and introduce the rather reluctant farmer to the fertilizers, the new seeds and their uses. Block Development Officers, Agricultural Extension Officers with the help of Village Level Workers are doing remarkable job in this direction. Arrangements that are necessary for successful farming are now being made. Seed farms and seed stores are being established and seeds are supplied at reasonable prices. Fertilizers, pesticides etc. are being supplied to the farmers ; arrangement for irrigation water with the help of deep tube wells is done wherever necessary. Since this strain is not known to West Bengal, elaborate arrangements were made to publicize the methods and technique of new varieties of paddy cultivation in the form of handouts and newspaper insertions, demonstration farms and special progr mmes in the Home Service of All India Radio to educate the masses. Personal contact with farmers were also very helpful in passing on the knowledge from the laboratory to the actual rice-grower. The soil and climate determine the dose and type of fertilizers to be used for optimum production. The soil testing laboratories, although very few in number are rendering this service free of cost. If sample testing of soil is systematically done, very soon data about all types of soil in West Bengal will be collected. A general recommendation has already been made about the use of fertilizers for different crops in the State. This could be further supplemented by more detailed data for specific purposes. The progress made in introducing the modern methods in the farming practices of the State may now be reviewed.

USE OF FERTILIZERS

As stated earlier, introduction of new varieties of seeds has been helpful in making the farmer more and more conscious about the variety of fertilizers in the crop farming.

Under the care and efforts of Fertilizer Association of India, all-out attempt throughout the country is being made to produce fertilizers of various nutrients (nitrogenous, phosphatics) and every year new factories are being established for producing fertilizers. A central pool of fertilizers is in operation which collects both inland production and imports and arranges for their distribution according to needs in various parts of the country, although a major part of the production of the factories in the State are consumed locally. In West Bengal, there were four factories in production in 1966. In between them they produce annually Ammonium Sulhate (9110 tonnes of nutrients), Superphosphates (17,890 tonnes of nutrients). Two more factories were under construction which were expected to produce Urea (145,000 tonnes of nutrients) and Super-phosphate (4130 tonnes of nutrient) when completed. As compared to above, the production in 1960 was Ammonium Sulphate (6300 tonnes of nutrient) and there was practically no production of other types of fertilizers within the State.

With the increasing demand, supply of fertilizers have kept pace and thus consumption of fertilizers per hectare of arable land has increased considerably.

In 1960-61 consumption of fertilizers (nitrogenous and phosphatic) was about 1.87 kg /hectare of arable lands. In 1965-66 consumption of fertilizers (nitrogenous, phosphatic and potash) was as follows :

Nitrogen 4.6 kg., phosphorous 1 06 kg., and potash 1.21 kg. (total 6.90 kg / hectare). If consumption of fertilizers is any indication of change in the outlook of the farmers in this State, it could be claimed on the basis of figures stated above, that there has been some progress in that direction. It would not be out of place to mention that fertilizers in West Bengal are not subsidised by the Government, the farmers have to purchase them at the usual market prices.

MECHANISATION OF FARMING PRACTICES

Although complete mechanisation is yet far off, demand for certain types of implements is gradually increasing. The aversion for mechanical implements is fast dying out. Usefulness coupled with necessity is helping these implements to gain grounds. In the cultivation of Taichung paddy, to take an example, spraying of insecticides even thrice a month may be necessary. The urge to raise more than one crop is gradually getting more common. On the other hand, to arrange for irrigating the fields for double cropping, pumping sets are essential. Sprayers and pumps of various descriptions at present have the highest demand. They are relatively less expensive and with the subsidy from the Government an average farmer can procure them on hire-purchase basis. Next to these, one can mention the popularity of seed drills and the wheel-hoe and the mechanical thresher. Every land owner is trying to procure them. The mould-board plough, an improved variety of local plough, has also found favour with the farmers. Tractors have not come into the picture to a great extent, because of their high prices. Some light imported Russian tractors are owned by a few farmers who are relatively well off. They have been found to be most useful. The Directorate of Agriculture is making arrangement for popularising these implements and making them available to all the farmers. An Agro-Industries Corporation has been formed on the Government level. This Corporation would get implements made through approved manufacturers. Specification of such implements are to be supplied by Corporation itself. A stock of all such implements will be maintained and supplied to the farmers on demand through Block Development Officers and other organisations. There is also a great demand for spare parts and work service centres. Work service centres should be established in villages, so that the farmer can get his implements repaired easily.

According to the policy adopted by the Government of India in the First and Second Five Year Plans, deep tube wells were sunk to provide water for irrigation. In 1967-68 there were about 119 deep tube wells in the State. The tube wells are run by electricity or oil engines, and are to be operated by a competent mechanic. In case of power failure, tube wells become useless. The result of their failure during hours of need might be disastrous. The capital expenses for setting up deep tube wells and the cost of their operation is high. The Government is therefore at present trying to popularize the shallow tube wells. Equipments and subsidy for establishing shallow tube wells have been made available, the farmers are enthusiastic enough to take advantage of the opportunity. The initial deposit money has been waived in case of farmers with 1 to 2.5 hectare holdings.

Livestock Census figures which also cover agricultural implements for the Census year 1966 are now available. If the number of agricultural machinery like oil-engines, pumps, electric pumps and tractors that were in use in various districts during that particular year are any indicator of the progress in mechanization, it is apparent from the census (Appendix Table-3) that progress in that sphere had been most encouraging Backward districts like Purulia and Bankura recorded remarkable improvement. In case of all districts within the Basin with the exception of Nadia there had been a big increase in the number of tractors; e g. in Howrah there were 426 tractors in 1966 in place of only one tractor recorded in 1961—an increase of 42,500 per cent. Similarly in Bankura there were 235 tractors as compared to only 4 tractors in 1961 an increase of 5775 per cent. On comparing the Census figures of 1956 and 1961 it is noticed that the rate of increase of farming machinery was not so high as as was noticed during the period 1961-1966. Perhaps this may be taken as a reflection of the fast-growing general awareness among the farmers regarding the usefulness of the farming machinery in the recent years.

SEED FARMS & SEED STORES

The vital part played by improved seeds in giving better returns is now fully realised by the farmers. The agricultural department is running several seed farms for raising seeds of high quality. Seed stores on cooperative basis have been established in most of the Development Blocks wherefrom the farmer can have quality seeds on loan and also pay back in the form of seeds after harvesting. Treatment of seeds with chemicals at various stages to make them free from diseases have become a common practice. Similar other needs of farmer's like cash loan during lean periods and purchase of seeds etc. were arranged through farmer's cooperative credit societies. In 1963-64 the position in West Bengal in this respect was more or less as follows :

Number of Societies	Membership ('000)	Paid up Capital ('000 Rs.)	Number of undertakings distributed
13,040	775	18,105	1245
Value of good distributed (in 000 Rs.)			
Seeds	Fertilizers	Other agricultural operations	Consumer goods
124	3260	446	1300

Source : Fertilizer Statistics in India—1967

EFFECTS ON OUTPUT

Rationalisation of the various aspects of farming had its effect upon the returns gained from the land. A comparative picture of yield per hectare of rice crop would speak of itself.

Yield of rice in kg./hectares

	1952-53	1955-56	1958-59	1961-62	1964-65
Aus	827	793	652	759	985
Aman	994	944	1010	1129	1271
Boro	947	1066	1018	1101	1190

Source : Statistical Handbook 1962-63 and Agricultural situation in India, March 1967.

The total output of rice, consequently has also increased.

Production of rice in '000 tonnes

1955-56	1961-62	1963-64	1964-65
4515	4798	5334	6763

Source : Fertilizer Statistics in India—1965-66

The enthusiasm to grow more than one crop particularly *rabi* crop from the same piece of land is gradually gaining ground. Although latest statistics are not available to substantiate the development, second or third crop in the form of vegetables, oil seeds particularly mustard, are getting increasingly popular. Area and production of potato (*rabi crop*) can be taken as indicator of this trend.

Potato

	Area in '000 hectares	*Production in '000 tonnes*
1955-56	48	395
1961-62	57	732
1963-64	65	560
1964-65	69	1066

Average area under jute also records a considerable increase, and as discussed earlier, land growing jute can be put under *aus* paddy as a second crop. It can therefore be expected that land under *aus* crop would increase keeping pace with the increase in the area under jute in the State.

Jute

Area in '000 hectares		*Production in bales*
1955-56	334	2029
1961-62	464	3379
1963-64	446	3296
1964-65	456	3646

Of late there had been a remarkable increase in the area that is being put under wheat in the various districts. Murshidabad leads in this respect followed by Birbhum and Nadia. (Appendix Table-1). The total area under wheat in the State as a whole, was 41,197 hectares in 1965-66 which in 1967-68 went upto 78,000 hectares and it was expected that in 1968-69 *rabi* season the area under wheat was to be over 127,000 hectares with an output of 272,000 tonnes. In districts like Midnapore wheat was seldom sown, whereas in 1968-69 about 7000 hectares of land was put under wheat. The yield was high because of the high yielding variety of seed used. The total production of wheat in the State in 1968-69 was high enough to enable the State Government to offer for sale its surplus stock to the Food Corporation of India.

MIXED FARMING

Under the condition of farming that prevails in this State a practice of mixed farming would have been useful. All the people that depend upon cultivation are not fully engaged throughout the year and perhaps the additional activity of rearing milch cattle or raising poultry for cash returns could be easily combined with their present day activities in farming. In the Basin (within West Bengal) such schemes have a good scope of success because the majority of the local population are non-vegetarian and marketing the products would not therefore be a problem.

The great metropolis of Calcutta, gets daily supply of milk mostly from professional milkmen or from the State-owned milk supply scheme which again collects cattle milk from its own sources or from milkmen living in the suburbs of Calcutta. Majority of milk suppliers to the Government Milk Supply Scheme are not farmers who combine dairying with farming and so cannot be said to be practising 'mixed farming' in the real sense of the term. No cooperative efforts like the Kaira district Cooperative (Amul) for milk production have grown up and so dairying, more or less, is still in the hands of professional cattle owners. Outside the Calcutta conurbation milk is scarce. Perhaps with some subsidy from the State, cooperative milk societies could be established providing some incentive to the peasants for taking up dairying as supplementary to crop farming.

West Bengal was selected among others as the State where intensive efforts were to be made for developing poultry keeping by 'Deep Litter' system. Efforts are being made, through Development Block Officers and other Government agencies, to distribute, free of cost, quality chicks. Veterinary clinics were in operation in many village centres providing medical advice and guidance in the matter of poultry-keeping. Production of eggs has increased considerably and farmers are gradually adopting poultry keeping. But once again schemes are mostly urban oriented and are more popular with people in the urban centres. In the absence of any detailed survey, it is difficult to say, how far this has promoted the conception of and the realisation of the advantages of mixed-farming among the peasant farmers. Traditions and ignorance die hard. It may be hoped that by means of sustained efforts the idea of 'mixed farming' may gain grounds in the economy of the peasant-life of the State.

CONCLUSION

There is no doubt that steps in the right directions have been taken in improving agriculture and food production in the Bhagirathi-Hooghly Basin (lying within West Bengal). All the factors that have a bearing on farming are receiving due attention of the State agricultural authorities and to some extent, of the farmers themselves. Conservatism and ignorance regarding farming methods are gradually being removed and cooperation, use of fertilizers etc. are being introduced. What is most encouraging is the fact that a general consciousness about the need of improving farming method is marked among at least a section of the peasants and the demand for improved seeds, better implements, insecticides, spare parts for implements etc. has considerably increased during the last few years. The rural market centres have now to cater for the needs of spare parts and provide servicing facilities for various types of agricultural implements now in use. If the supply of seeds, fertilizers and water for irrigation can keep pace with the increasing demand of the farmers, one may expect that in the next decade, the part of the Basin will be able to put up a better picture and a more impressive performance in the agricultural sector.

APPENDIX

TABLE—1

*Area under chief crops of Bhagirathi-Hooghly Basin within West Bengal**

(in '000 hectares)

Districts	Aus	Aman	Boro	Wheat	Gram	Sugar cane	Oil seeds	Jute
Bankura	48.3 (44.3)	284.9 (300.3)	0.2 (0.9)	4.6 (2.3)	2.7 (2.7)	1.6 (2.5)	6.1 (4.1)	0.8 (1.4)
Birbhum	33.0 (33 1)	277.9 (281.2)	0.2 (0.4)	6.1 (7.6)	13.0 (10.8)	3.0 (3.9)	2.3 (5.0)	0.3 (0.08)
Burdwan	20.5 (24.4)	415.0 (436.0)	1.3 (1.6)	2.8 (3.8)	10.4 (9.4)	3.1 (4.9)	2.4 (3.4)	8.6 (9.8)
Hooghly	9 5 (7.1)	168.8 (176.9)	1.5 (1.2)	0.5 (0.3)	3.8 (2.0)	0.8 (1.4)	1.3 (1.2)	28.4 (34.4)
Howrah	1 0 (1.1)	83.7 (84.6)	1.2 (—)	— (—)	0.4 (0.4)	0.4 (0.2)	0-5 (0.08)	5.8 (4 9)
Midnapore	50.9 (48.9)	773.7 (792.0)	3.5 (3.2)	0.7 (0.2)	2.7 (1.1)	1.3 (2.4)	6,1 (5.0)	14.2 (13.3)
Murshidabad	78.6 (81 8)	195.4 (200.6)	1.9 (3.3)	18,6 (16.0)	54.5 (49.7)	5.3 (7.2)	26,6 (27.8)	51.6 (51.7)
Nadia	93.8 (104.0)	86.7 (91.0)	0.5 (0.9)	5.6 (4.0)	58.7 (51.9)	3.1 (8.2)	17.5 (31.4)	33.1 (54.9)
Purulia	4.1 (3.3)	222.9 (251.1)	—	0.1 (0.2)	0.8 (0.8)	0.9 (0.8)	1.8 (1.9)	0.4 (0.2)
24 Parganas	29:9 (28.1)	565.0 (571.1)	0 2 (0.2)	0.2 (0.5)	11.3 (8.1)	1.1 (2.0)	3.7 (7.8)	37.1 (49.2)
Total	369.6 (376.1)	3074.0 (3184.8)	10.5 (11.7)	39.2 (34.9)	158.3 (136.9)	20.6 (33.5)	68.3 (87.68)	180.3 (219.88)

* First figures are average for 1951-59 and figures within brackets are average for 1964-66

Source : (i) Agricultural situation in India, Jan. 1967 & Jan. & Feb. 1968.
(ii) Statistical Abstract, West Bengal 1960.

TABLE—2

*Bhagirathi-Hooghly Basin within West Bengal : Production and Yield rates of Rice-crop**

Districts	Aus		Aman		Boro	
	Production	Yield rate	Production	Yield rate	Production	Yield rate
	(in Tonnes)	(kg./hectare)	(in Tonnes)	(kg /hectare)	(in Tonnes)	(kg./hectare)
Bankura	38,200	791	335,000	1176	200	1000
	(41,700)	(941)	(436,300)	(1452)	(1,000)	(1111)
Birbhum	37,200	1127	347,700	1251	200	1000
	(41,400)	(1250)	(405,900)	(1443)	(700)	(1750)
Burdwan	21,600	1054	529,000	1275	1,600	1231
	(29,600)	(1166)	(662,800)	(1520)	(1,800)	(1125)
Hooghly	9,900	1024	194,500	1152	1,400	933
	(7,400)	(1042)	(236,900)	(1339)	(1,400)	(1167)
Howrah	1,000	1000	84,100	1005	1,000	833
	(1,100)	(1100)	(105,400)	(1258)	(—)	(—)
Midnapore	34,200	672	784,300	1014	3,300	943
	(42,400)	(867)	(957,700)	(1209)	(3,000)	(938)
Murshidabad	52,800	672	201,600	1032	2,000	1053
	(70,900)	(867)	(264,900)	(1321)	(3,000)	(909)
Nadia	78,400	836	66,0 0	761	5,000	1000
	(114,800)	(1104)	(106,500)	(1170)	(1,100)	(1222)
Purulia	4,200	1024	279,100	1252	1,000	—
	(2,300)	(697)	(321,300)	(1280)	(—)	(—)
24 Parganas	27,700	926	542.800	961	2,000	1000
	(34,000)	(1210)	(728,500)	(1276)	(200)	(1000)

* First figures are averages for 1951-59 and figures in brackets are averages for 1964-65.

Source : Agricultural Situation in India—January 1967.
Statistical Abstract : West Bengall 960.

TABLE—3

Agricultural machinery in Bhagirathi-Hooghly Basin of West Bengal Comparative picture 1961-1966

Districts	Tractors			Oil engines with pumps for irrigation purposes*		
	1961	1966	Percentage Variation	1961	1966	Percentage variation
Bankura	4	235	5775.00	101 (3)	134 (7)	32.67 (133.33)
Birbhum	5	86	1620.00	439 (100)	1366 (212)	211.16 (112.00)
Burdwan	25	49	96.00	75 (50)	167 (53)	122.67 (6 00)
Hooghly	8	52	550 00	284 (1)	8 (13)	—97.18 (1200.00)
Howrah	1	426	42500.00	73 (36)	285 (161)	290.41 (347.22)
Midnapore	29	242	734.48	773 (4)	356 (18)	—53.95 (350 00)
Murshidabad	29	44	51.72	49 (8)	24 (14)	—51.02 (75.00)
Nadia	73	56	—23.29	34 (12)	2 (41)	—5.88 (241 67)
Purulia	7	60	757.14	29 (5)	98 (44)	237.93 (780.00)
24 Parganas	15	49	226.67	285 (25)	318 (—)	11.58 (—100.00)

* Figures within brackets are for Electric pumps for irrigation purposes.

Source : Livestock census reports 1961 & 1966 (Data only).

REFERENCES

Govt. of India (1967) : *Agricultural Situation in India* (Monthly)-January.

Govt. of India : Fertilizer Statistics in India— 1964-65 & 1967-68.

Govt. of India : Livestock Census Report, 1967, 1961 & 1966.

Govt. of West Bengal : State Statistical Abstract—1961-62 & 1962-63.

Govt. of W. Bengal (1967) : *Vasundharā* (monthly), Māgh 1374 i.e. Jan/Feb 1967.

Mukherjee, S. N. (1956) : *A Brief Agricultural Geography of West Bengal*, Direct. of Agri., Govt. of W. Bengal.

LAND-USE IN RELATION TO FLUVIAL ECOLOGY IN THE BHAGIRATHI-JALANGI RIPARIAN TRACT : NADIA DISTRICT.

KANAN CHAKRABARTI

Abstract

Although man adapts himself to the most varied conditions, the natural factors such as relief, soil, climate, hydrographic conditions etc. are to a great extent responsible for the cultural set up which ultimately evolves in the region and gets reflected in the landuse of the area. The author in this article has attemped a landuse survey with particular reference to the fluvial ecology.

Although man's genius adapts itself to the most varied conditions, yet it is the natural environment, made up of relief, soil, climate, hydrographic conditions and so forth, which is responsible in general for the cultural set up, land-use and social phenomena of an area.

The area of study (Lat. 23°25′ N to 23°49′ N and Long. 88°8′ E to 88°33′ E) is an outcome of fluvial interaction and the year to year modifications, if any, have also been displayed by the rivers. The riverine character of the area is reflected in its linear settlement pattern along the rivers and other water bodies, agrarian economy of the area and the absence of industrial activity (excepting few cottage industry) or most of other secondary occupations. But with the shifting nature and the deterioration of the river Bhagirathi and its tributary Jalangi, the cultural landscape of the area changed. In consequence, the old settlements are lying far away from the river channels and new ones have grown along the communication lines—Eastern Railway, National Highway 34, and few settlements along shifted water courses of the Bhagirathi The agricultural practices also changed in respective sectors.

RIVER SYSTEM

The whole area is a net work of moribund rivers and streams, but the rivers Bhagirathi and Jalangi took the leading part in moulding the landscape. The meandering course of the Bhagirathi like a pendulum oscillates from side to side. The swing belt was thus originated, which depicts all the past movements of the river and also ensures a feature trend. So, the effect of shifting of the river on land-use pattern is of great importance In the channels of the feeders, changes are incessant, while in individual portions, alternations are continually taking place, loops being formed, cut through and reformed, so that traces of the old channels in the form of semi-circular jhils or lakes are frequent along the banks, the rivers as a whole have preserved their general characters and directions for a considerable time.

In Rennell's survey of the Nadia District, (1772), the only portions of the Bhagirathi channel which have retained its alignment are the straight sections from Jiaganj to Murshidabad and at Berhampore. The reason why this channel did not change shape very much in this portion is probably due to the embankment on the left bank, but between the sections, Motijhll is left as a relic of the main channel where a loop in Rennell's survey has been cut through and below to Plassey to which place the embankments continue, changes have been considerable. Katwa has apparently always been on the river bank, but between this town and Nabadwip, the channel has wandered over a large tract, and Agradwip which in Rennell's time was on the left bank, lay on the right bank of the river for years previous to 1913, when the cutting through of the Agradwip loop transferred it again to the left bank. Rennell's map also shows traces of the old channel, the change which brought Nabadwip from the left bank to the right bank.

The Jalangi shows similar changes but in certain portions, particularly the lower sections between Patikabari and Krishnagar, the formation of the bends have been well preserved. As a matter of fact, this section gives the appearance of a river with well-formed and established banks in places, probably in less friable material and so less subject to erosion.

In relation to the change of the river courses, it is important to note that the cardinal factor in the later history of the region has been the eastward shift of the Ganga waters from a main outlet along the western margins—the Bhagirathi-Hooghly to the present main course—the Padma-Meghna. Whether this is mainly due to alluviation at the off-take or to tectonic changes, or to shifts in the isostatic balance of the Delta itself, or to changes of course outside of the region (e.g. the great shift of the Tista), or to a secular swing to east, are questions which admit of large and inconclusive debate. We might then envisage a swing to and fro analogous on a vaster scale to the lateral wanderings of stream meandering across its flood plain.

From the study of the Survey of India's toposheets[1] of 1916-17, 1956-57 and the field map for 1968-69 (which was prepared by the author on her own observation Fig. 1) it is obvious that in 1916-17 the rivers were in a flourishing condition with numerous spill channels, creeks etc, while by 1956-57 many of the spill channels, bils and marshy areas had dried up allowing only drainage during the monsoons. The Bhagirathi too had become more silted up, encroaching towards the west having Agradwip on the left bank although it was formerly on the right bank of the river. In 1968-69 the river Bhagirathi along with Jalangi seemed to flow through misfit channels.

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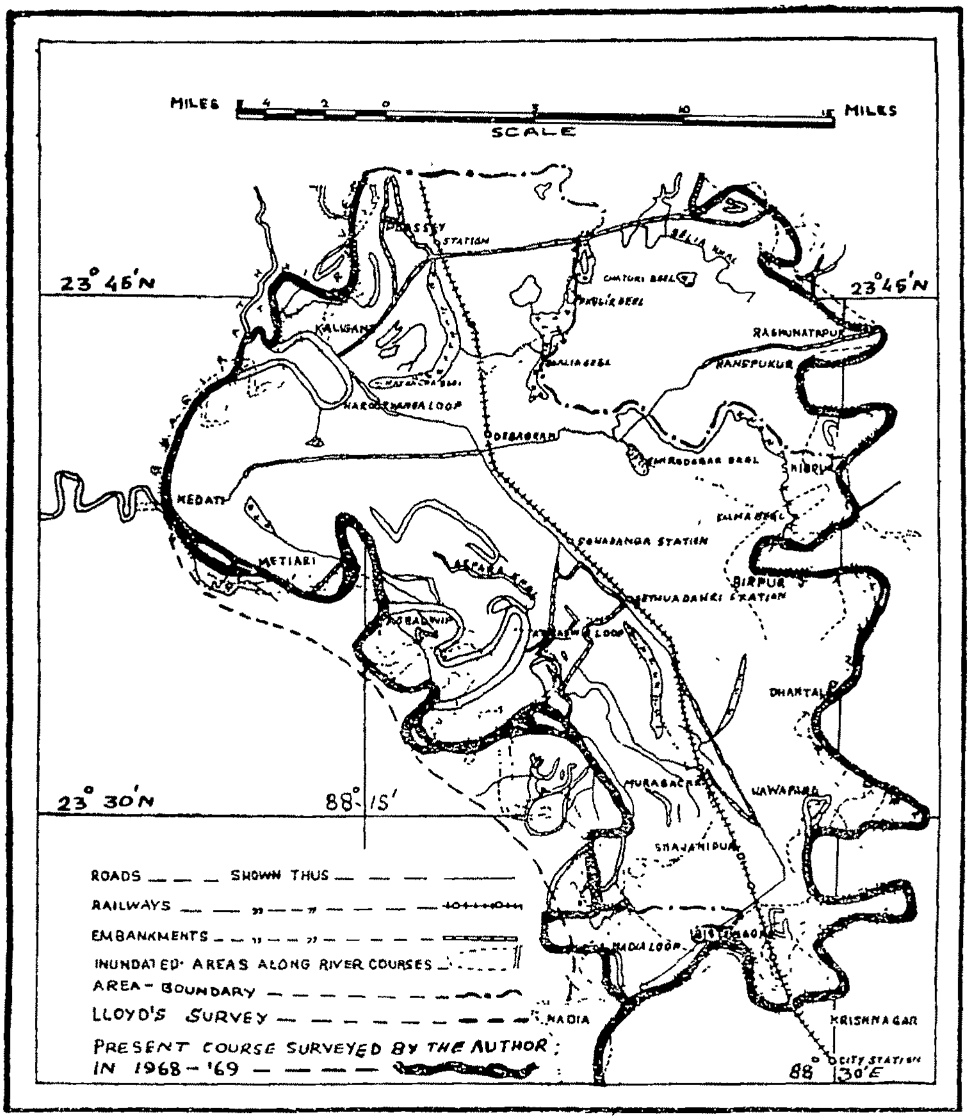
1. 79 A/1, 2, 5, 6, 7, 10.



Map of Nadia Rivers—The details of the map have been reduced from surveys made in Season 1916-17 by Survey of India. The superimposed details in dotted lines show approximately the courses of the Bhagirathi and Jalangi rivers as surveyed by Rennell about 1765

Fig-1

The maximum drainage density in 1968-69 was 1.5 miles per sq. mile, which was 2.5 miles per sq. mile during the period 1916-17. This reduction in the drainage density has been caused by the gradual reclamation of the cutoffs or bils together with the decay of the rivers Bhagirathi and Jalangi.

LAND USE

The migration and deterioration of the rivers have produced varied riverine topographic features of ups and downs with resultant differences in soils. These areas are the representatives of different uses to which the land is put (illustrated in Fig. 2). Water available both from the atmospheric precipitation and the adjoining rivers—Bhagirathi and Jalangi, is the main criteria for their specifications.

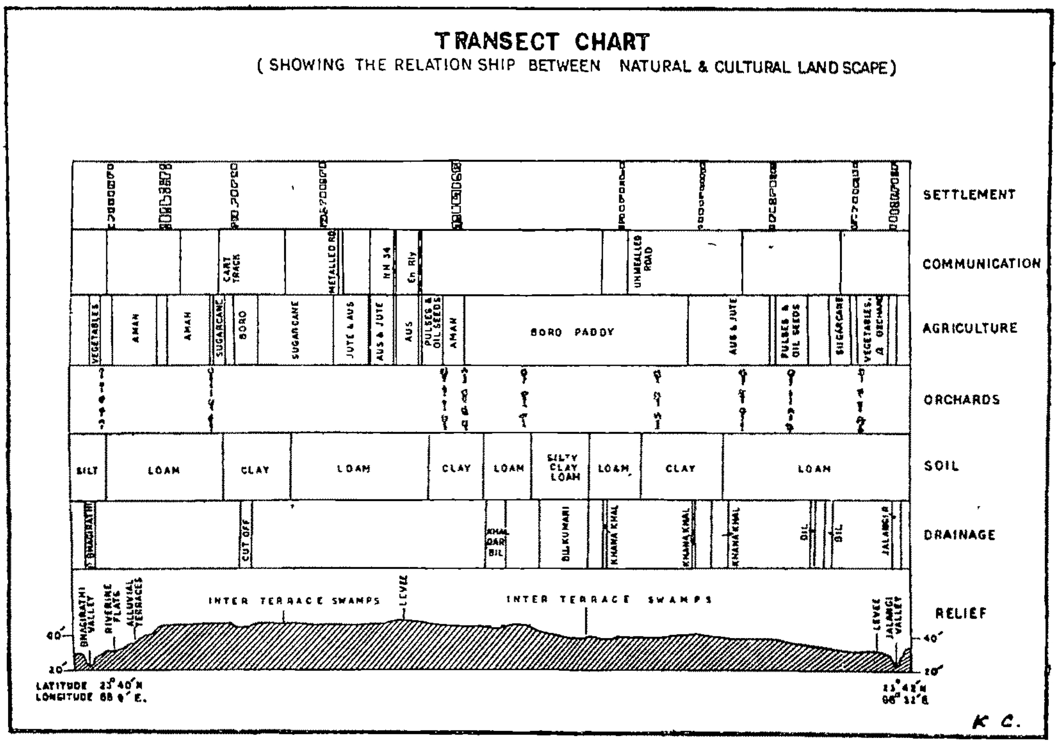


Fig-2

The upper-terraces of loamy sand, lying beyond the limit of occasional floods of devastating nature, have been devoted to homesteads surrounded by orchards. Pulses and oilseeds, which require a few showers of rain and favour higher grounds of inferior soils, are partially pract'sed. Cart tract for inter-village communication is also built up here.

The lower terraces of silty-loam are well utilized for market gardening. Inter-culture is always favoured for varied products of different values. Fertility of the land is, somehow, maintained by the additions of silts during seasonal floods.

The lands composed of silty clay downwards from the lower terraces are preferred for paddy culture. The high clay content with a proximity of the water-table to the surface during rains makes the area suitable for *aman* paddy, especially its deep-water variety. Low lying tract, liable to occasional floods and flash flow, is favoured by *aman* paddy, although *aman* receives most of its water from the atmospheric precipitation.

A much higher land, preferably a well-drained area is suitable for *aus* paddy. *Aus* fields, which are located at a distance from the rivers, are absolutely dependent on the rain water, although recently Government constructed shallow tube-wells supply water for these fields to a considerable extent. Sugarcane along with *aus* is also grown.

Boro paddy and jute require much water. Water available from the monsoons is restricted to three to four months in a year, while for rest of the year these crops are to depend on rivers, where irrigation work is of little help. They are cultivated in marshy areas and areas immediately adjacent to the rivers, bils, and spill channels etc.

ECONOMIC SET-UP

Thus, during rains, except for the spaces occupied by homesteads and orchards, the whole expanse goes under cultivation. Although in times of floods the entire tract gets submerged with the resultant damage to agriculture and the riverine effect is directly visualized. But with the advance of drought the landscape takes another appearance. As the bils, waterlogged areas and ponds get dried up and the water of the well reaches its lowest limit, the cultivation in the terraces farther inland is a remote possibility. But the irrigation projects sponsored by the Government yield a satisfactory result in some places. The lands immediately on the river banks are only cultivated with water-melon, gourd, kusumseed etc. as the soils have a fairly good moisture status with a proximity to the river-water.

From the point of view of its year-round agricultural use and the overall per capita income the sets of terraces adjacent to the river banks, may well be classified as the best or the first class land, the second, third, fourth classes of land appearing successively as we proceed inland from the river banks. The sets of terraces, designated today as the worst ones from the point of view of agricultural uses were once distinguished as the best productive. With the migrating nature of the rivers the balance of productivity is always changing.

Occupational Structure :

In order to bring out the economic pattern of the area a study has been made with reference to the occupational structure in 1951 and 1961. In 1951 the agricultural population constituted about 75 per cent of the total, while commerce and transport comprised 7 per cent and other services 18 per cent. But the percentage of agricultural population came down to 70 per cent in 1961. Still agriculture continues to be the leading occupation of the people of this region. This agrarian economy is the resultant factor of the riverine influence. Heavy pressure of population on arable land coupled with conditions of backward technology and organisation has resulted in severe under employment of labour and low output per person. In spite of the high fertility of the soil, the yields of major crops per acre are relatively low. Paddy is the predominant agricultural crop occupying about 70 per cent of the total arable land. In case of rice, for example one acre of land produces only 679 lbs. This is due to the repeated use of the same land year after year without being aided by natural fertiliser (river borne silt) and indifferent amount of fertilizers such as super phosphates, nitrogen compounds, etc. This is really a serious handicap for the region where agriculture dominates.

CONCLUSION

In consequence with the deterioration of the Bhagirathi-Jalangi and restriction of spill action of rivers, soils have become unproductive, river navigation even by country boats has become insignificant affecting the trade and commerce of the region. Devastating floods often destroy the lives and properties. Moreover, the existence of the port of Calcutta—handling a big part of Indian trade—depends on how long the Bhagirathi-Hooghly can be kept alive. The Ganga Barrage Scheme proposed by the Government of India seems to be a possible solution of this vast and complex problem, and we may be optimistic about the future when there will be considerable improvement in the flow of the Bhagirathi. Agriculture, trade and commerce will prosper with the restoration of the navigation routes and the region will be restored, to an extent at least, to its former level of prosperity.

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REFERENCES

Bagchi, Kanangopal, (1944) : *The Ganges Delta,* Calcutta University Press, Calcutta,—157 p.

Basu, S. R. (1965) : *A study of the meander belt of the Bhagirathi river.* Calcutta University, M. A. Thesis. (Uupublished).

Basu, S.R. (1968) : *Landscape evaluation—A methodology.* Geo. Rev. of India., Vol. XXX, No. 4, Dec.

Colebrook, R.H. (1801) : *On the course of the Ganges through Bengal* : Transactions of the Asiatic Socity of Calcutta, Vol. VII, 1801.

Coulson, A.L. (1940) : Memoirs of the Geological Survey of India, water supply, paper No. 1., Vol. LXXVI.

Chatterjee, S.P. (1945) : *Land utilization in the District of 24-Parganas.* Cal. Geo. Soc. Calcutta.

Chakrabarti, K (1969) : *Land-use in relation to the fluvial ecology in the Bhagirathi-Jalangi riparian tract*—Calcutta University, M.A. Thesis, (Unpublished).

Govt. of West Bengal (1956) : *Provisonal Settlement Report.* Collected from the Land Records Department, West Bengal.

Mukherjee, R.K. (1938) : *The changing face of Bengal,* Calcutta University Press, Calcutta, 288 p

Reaks, H G. (1919) : *On the physical and hydraulic characteristics of the Rivers of the Delta.* Report on the Hooghly river and its head waters, Calcutta.

Rennell, J.J. (1781) : *The Ganges and Brahmaputra Rivers* : Royal Society, London Philosophical Transactions, Vol. LXXI.

Roy, B. (1967) : *District Census Handbook,* 1961, Nadia. West Bengal.

Sen, C. (1947) : *Agricultural Statistics by Plot to Plot Enumeration 1944-55,* conducted by H S M. Ishaque, Part III, Union Tables, Bengal Govt. Press, Alipore.

AGRICULTURAL INPUT CHARACTERISTICS IN SOME PARTS OF BURDWAN DISTRICT

SAUMYANANDA CHATTEJEE

Abstract

In order to feed their teeming millions, developing countries need improvement in their agricultural producttion. India, and in particular the Burdwan district, with best soil conditions, is no exception to this. To improve the agricultural output and to boost up yields of the different crops produced here, some improved techniques have been introduced. In this article there is brief discussion about changes in input characteristics due to the application of newer irrigation methods and its impact on crop cultivation.

For several centuries India's land resources have developed through trial and error method. This had led to archaic uses of land. Recently, however, attempts are being made to modernise agriculture through the adoption of scientific techniques and classification of the lands for best uses. In certain parts of the country, e.g. the Burdwan district in West Bengal, some of these techniques have been adopted to improve agriculture. To evaluate the exact nature of development due to introduction of new techniques, a type region consisting of two noncontiguous tracts have been selected for comparative study. These tracts include irrigated villages in P. S. Galsi and non-irrigated villages in P. S. Katwa. The results of introducing larger inputs by way of improved seeds, manure and irrigation have been studied here. The term input or cost generally refers to the outlay of funds for productive services. This is directly related to the laws of production, their structure is determined by the nature of the production function as well as by the level of prices and nature of the market for productive services. For purposes of scientific analysis it would be necessary to build the input functions in the agricultural economy in the two regions of study and relate them to the value of the services flowing from the diffirent categories of resources. For this purpose intensive collection of all the data and painstaking analysis of material is needed. Due to the lack of sufficient data a modest attempt to study the nature of the inputs in made here.

Input data regarding seeds and manures have been available fcr 800 and 400 farms in the two zones, and no data were available for another 20 farms and

10 farms in the above two zones respectively.

Cost of seed has been computed for both the seed in the cultivators' own stock and that purchased or borrowed from others. The seed in his own stock has been evaluated on the basis of the price paid by him if purchased or on the basis of the price paid by other cultivators for the particular seed. A similar procedure has been adopted for manures and fertilizers.

TABLE—1

Input of seeds and manures

Zone	No. of Farms	Area in acres	Aggregate expenditure for seeds in in Rs.	Aggregate expenditure for manures in Rs.	Per farm/Per Acre	
					Cost of seeds in Rs.	Cost of manures in Rs.
1	2	3	4	5	6	7
Irrrigated Zone	800	3,179	31,172	121,826	36.00/10.00	140.00/45.00
Non-Irrigated Zone	400	1,353	15,120	21,080	36.00/10.00	50.00/16.00

It has been observed that the cost of seeds for sowing in an acre of land is more or less equal in two areas. This equality in the amount of seed/acre in the two areas may perhaps be the result of a technical relationship between the area sown and quantity of seed. On the other hand, differences do exist in the per acre cost of manures and fertilizers used in the different zones. It suggests that if new scope of a higher agricultural production and income continue for a number of years, investment in this item of working capital increases significantly.

From tables correlating yield per acre and amount of manures used per acre in each of these zones, a positive correlation is suggested between the quantity of manure used and higher productivity, that is to say, if more manure is used, the prospect of better yield is always there, whether or not irrigation facilities are available. It may be concluded that the better yields in the irrigated zone for a number of years have increased the income of the peasants, and hence their power to spend more for manures. The difference between the per acre yield in different areas of irrigated zone is small, whereas it is more when compared with the non-irrigated zone. This suggests that increased use of manures is associated with increased yield. Utilization of irrigation water is associated with increased yield to a much greater extent.

In any agricultural production labour plays a predominant role. So the pattern of labour output has been discussed here in detail. The input of labour can be classified into two categories—hired labour and labour put in by members of the farm household.

Some farms employ more hired labour, some depend more on the family members. It is usually the bigger farms that employ more hired labour.

Due to the predominance of *aman* paddy human labour for *aman* cultivation has been discussed here.

TABLE—2

Input of human labour for cultivation of aman paddy

Zone	No. of Farms	Amount of land under aman (in acres)	Employed Man days	Family Man days	Total Man days (4+5)	Cost of Man days Rs.	Total cost Rs. (6x7)
1	2	3	4	5	6	7	8
Irrigated zone	800	3,179	164,626	115,130	279,756	5.00	1,398,780.00
Non-irrigated zone	400	1,353	53,498	53,250	106,748	4.00	426,992.00

TABLE—3

Cost of cultivation

Zone	Per acre Man Days			Per acre cost of labour		
	Hired labour Rs.	Family labour Rs.	Total labour Rs.	Hired labour Rs.	Family labour Rs.	Total labour Rs.
Irrigated zone	60.00	40.00	100.00	132.35	92.00	224.35
Non-irrigated zone	41.50	41.50	83.00	70.00	70.00	140.00

While the number of family man-days put in on an acre of *aman* land is about the same in the two zones, the number of hired man-days differs significantly from zone to zone. The suggestion may be made that higher agricultural productivity in irrigated villages has enabled the farmer to spend more for hired labour and thus resort to more intensive cultivation. It is equally true to say that more intensive cultivation is rather the cause than the effect of higher productivity in *aman* cultivation. Higher agricultural incomes in the irrigated villages seem to have favourably influenced the rate of wages paid to agricultural workers in addition to the provision of a greater volume of employment of hired labour. This is an indirect benefit of irrigation in the irrigated region.

Animal labour is chiefly supplied by bullocks possessed by or hired by the farmers. In a few cases, buffaloes also are used as draught animals. It is found that the proportion of farm households in the two regions which do not possess any draught animal are 25 per cent and 30 per cent respectively. It is also found that the average value of investment in draught animals is highest in irrigated villages. The animals work either for the whole day or a part of the day. Therefore, it has been considered more suitable to gather data regarding animal labour in terms of bullock hours than in terms of bullock days. The following table gives an idea of the same.

TABLE—4

Input of animal labour for cultivation of aman

Zone	No. of farms	Total acreage	Total No. of Bullock hours	Total cost in Rs.	Per acre	
					Bullock hrs.	Cost in Rs.
Irrigated Region	800	3,179	4,22,587	81,607	1,517	25.00
Non-irrigated Region	400	1,353	196,543	30,200	141	22.00

That more bullock hours are employed in the irrigated zone per acre of land growing *aman* crop is evident from the above figures. The per farm average tells a different srory because the amount of land per farm in the irrigated zone is higher than the non-irrigated zone. This is an evidence of more intensive farming in the old-irrigated zone which also employs animal labour to a greater extent.

Besides the above factors there are other input factors which should also be considered, e.g. agricultural loans, hired labour, etc constitute an important item of input.

A study of disbursement of agricultural loans reveal that it is more in the irrigated villages and less in the non-irrigated villages.

Depreciation on implements and machinery has been noted during investigation. It is seen that aggregate value of annual depreciation of all implements in all the farms for which data were available, is more in irrigated areas than in non-irrigated lands.

The system of leasing out land on long term basis is not much in practice in this region. On the other hand, the system of share-cropping is extensively practised. Share-croppers are given the land from year to year on contracts which stipulate the payment of half the crops by way of rent. In order to estimate the average rent paid on an acre of share-cropped land, the total value of crops and their by-products paid to the owners of land by the share-

TABLE—5

Per acre rent paid on land lease from others

Zone	Av. Yield of Aman/ acre (mds.)	Percentage parted with	Quantity of crops parted with (Md.)	Value in Rs.	Value of by-product parted with (in Rs.)	Total value on an acre of share-cropped land (in Rs.)	Percentage of total land cultivated by the share cropper	Av. rent paid per acre in two zones (in Rs.)
1	2	3	4	5	6	7	8	9
Irrigated	24.00	50.00	12.00	254 00	34.00	288.00	32.00	96.00
Non-irrigated	20.00	50.00	10.00	90.00	26.00	116.00	25 00	56.00

TABLE—6

Computed Rent : On own Land

	Total value of rent paid on an acre of sharecropped land in Rs.	Percentage of land cultivated by the owner	Average value of computed rent in Rs.
Irrigated	288.00	68.00	195.84
Non-Irrigated	116,00	75 00	87 00

TABLE—7

Per acre cost of production of aman paddy (in Rs.) : Operational cost

Zone	Seed	Manures	Animal labour	Hired labour	Family labour	Depreciation & repair	Interest on loans	Total (2+3+4+5+6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Irrigated	10.00	45.00	25 00	132.35	92.00	17.00	2 00	323.35
Non-Irrigated	10.00	16.00	22.00	70.00	70 00	17.00	2.00	207.00

croppers in each of the two areas was first calculated. Calculation was also made of the proportion of *aman* land cultivated by share-croppers out of the total land under *aman* cultivation in the two zones. The products of the respective values and proportions give the average rent per acre on share-cropped land for each zone.

When the owner cultivates his own land, the presumption is that, if instead of cultivating it on his own account he let it out to share-cropper, he could get an amount of rent equal to that paid by the share-croppers in the village on similar other lands. Thus the computed rent on own lands is shown in Table-6.

TABLE—7 (contd.)

Overhead cost

Rent on leased land (10)	Computed Rent on own land (11)	Interest on fixed capital (12)	Irrigation charges (13)	Total (14)	Total cost of production 9+14 (15)
96 00	195.84	6.00	10.00	307.84	631.19
56.00	87 00	6.00	—	149.00	356.00

TABLE—8

Net profit from cultivation of aman/acre (Rs.)

Zone	Total output	Total input	Net profit or loss
Irrigated	720.00	631.19	88.81
Non-irrigated	400.00	356.00	44.00

All the items of input discussed above may be combined into two broad groups. Corresponding to the two components of (1) operational costs and (2) overhead costs. (Table 7).

It seems that the cost of each different item is higher in irrigated zone, due to higher cost in hired human labour, irrigation charges and also due to the fact that the wages of the family labour have been calculated on the basis of the wages of hired labour.

There is an unmistakable evidence that farm business income from the cultivation of *aman* crop is higher in irrigated villages than in non-irrigated villages. This is due to hired human labour and manure, fertilizer and irrigation charges. If all the items of input are included, then gross output turns out to be slightly higher than total input in each zone. *Aman* is the most important and profitable crop in this region and constitutes about 70 per cent of the total agricultural produce. Nevertheless the features of subsistence farming are revealed in the cultivation of this crop. Farming in this region is carried out not because farming is profitable, but for the computed incomes i.e. rent on own land, interest on own capital, wages of family labour, etc. that farmers engage in cultivation. It appears that the pressure of population being very great in the whole region, output per unit of land is more important than output per unit of input.

CONCLUSION

In the above analysis no striking change in the existing pattern of agriculture has been assumed. The area is located in one of the fertile regions of India, so, there is no ostensible reason why a three-crops a year programme after the pattern of the Egyptian agriculture, should not be possible there. Agricultural planning for this area ought to be taken to overcome the difficulties not met by the improved irrigation facilities. This should include proper drainage, sinking of deep tube wells, soil improvement and conservation, better manuring, better seeds and scientific crop rotation and other improved agronomic practices. Irrigation when accompanied by such measures ought to bring about a big rise in the per acre output of rice and other crops. From the angle of marketing the agricultural produce the area is more favourably situated than many other part of India. Diversified pattern of agriculture in place of monoculture of rice in order to meet the demand for milk, egg, meat, potatoes, fruits etc., will yield a higher income than the cultivation of only foodgrains.

Whatever improved techniques are introduced their full benefits can not be enjoyed unless the land-tenure system is completely changed. There should be full protection of security to tenant cultivators. There should be a new approach in the use of land by land consolidation, improved land management, efficient use of water resources and extension of credit services to the farmers. A regional approach to agricultural development would facilitate and will help in the optimal use of land and other resources of the area from the long term view and in a systematic approach to crop planning and intensive use of man-power.

REFERENCES

Azzi, G, (1956) : *Agricultural Ecology.* Constable & Co. London, 424 pp.

Mitra A. (1953) : *Account of Land Management in West Bengal.—1870-1950,* West Bengal Govt. Press, Alipore. 312 pp.

SOME ASPECTS OF AGRICULTURE IN DAMODAR-HOOGHLY INTERFLUVE

R. BHATTACHARYYA AND SANKAR DE

Abstract

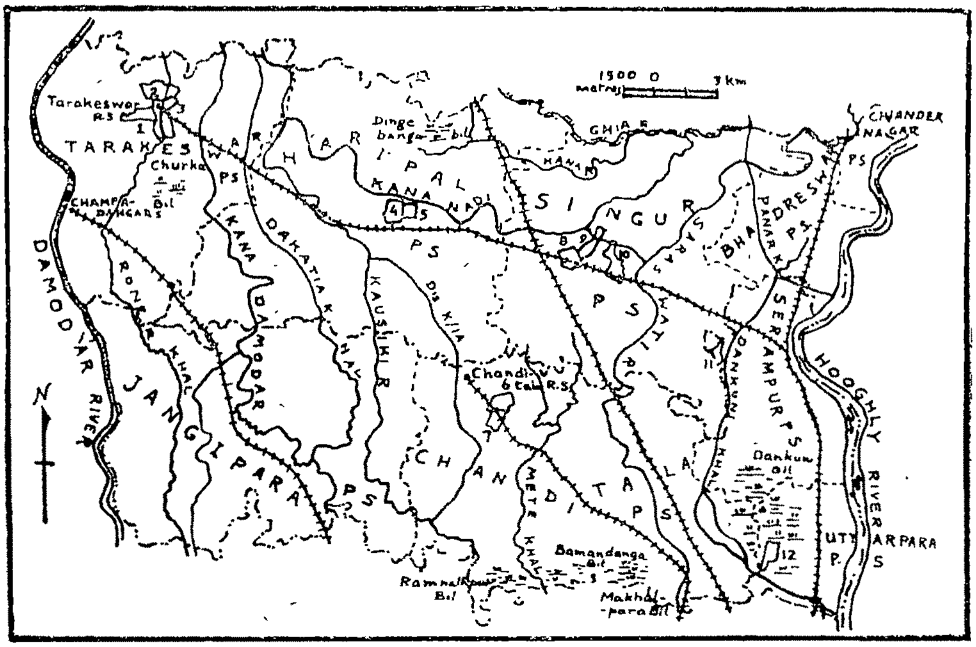
The agriculture of the southeastern part of Hooghly district—the Damodar-Hooghly interfluve—represents a striking feature in the field of agriculture within the alluvial tract of Bengal. In this area about 34.10 per cent of the working population live on agriculture. and agriculture occupies 78 per cent of the land. This agricultural land is unevenly distributed, while 4 per cent of the land is under cultivation in the east, 80 per cent of the land is under cultivation in the west. Multiple cropping is the pattern in the northeast, whereas single cropping is the rule in the rest of the area.

By studying 12 *mauzas* it has been found that farmers adopt better implements, seeds and the inorganic fertilizers when they are nearer to demonstration farms or nearer the urban agglomerations. In the irrigated tracts demand for irrigation water is rising steeply, while supply position is not keeping pace with it. Bad communication facilities are also retarding the growth and modernisation in agriculture. A comparative study of land under different crops indicates, phenomenal rise in *aus*, *boro* and high-yielding paddy and wheat. *Aman* lands are steady. Jute and potato show fluctuations. Oil seeds, tobacco, maize, garlic, betel leaf show increase while pulses and vegetables show a decreasing trend.

The area under investigation is an interfluve (*Doab*) between the rivers Damodar on the west and the Hooghly on the east. It extends between 22°40′ N and 22°55′ N latitude and from 87°51′ E to 88°24′ E longitude. The eastern and western boundaries are riverine, while the northern boundary is formed by the administrative boundaries of the police stations of Dhaniakhali, Polba and Chinsurah. The southern boundary too, is the administrative boundary between the districts of Howrah and Hooghly. Thus demarcated, the *study area* is rectangular in shape, with an area of 915.5 km^2 and a population of 1,061,360 persons (1961). This area extends for about 38 kilometres from east to west and in the north-south direction it varies from 22 to 26 kilometres. The administrative divisions are **the subdivisions** of Chandernagar and Serampore. (Fig.-1).

PHYSICAL LAY-OUT

Physiographically, the entire area is a flat alluvial plain interrupted by a number of sluggish rivers and marshes. The village sites are raised and with the high river levees add variety to the landscape. The Hooghly and the Damodar are the only important rivers and the other streams are either old courses of the Damodar e.g. the Kana Damodar, the Kana Nadi etc., or distributaries of the Bhagirathi-Hooghly like the Saraswati river. A feature of prominance is the levee on the right bank of the Hooghly river and man-made embankment on the left bank of the Damodar. The Hooghly levee regionally slopes from north to south. The bench marks at Chinsura, Serampore and Kotiung are 8.2, 7.6 and 6.1 metres respectively. It is continuous within the region with an occasional gap and having a width varying from 800 metres at Kotrung to 2,400 metres at Serampore and Chandernagar. Areally this levee slopes westward adding to the drainage problem of the western land.



1. Bhata, 2. Bhanjipur, 3. Tarakeswar, 4. Brehmanpara, 5. Hamirgachhi, 6. Aushbali, 7. Chhunche, 8. Kismat Apurbapur, 9 Gazipur, 10. Mallikpur, 11. Chakpatakharia, 12. Basipota.

Location of the Area with drainage and Administrative divisions.

Fig. 1

The Damodar embankment erected to contain the river and similar efforts are also seen in other areas of this *study area* mainly in the north-central portion. They are built to protect roads, railways and also settlements. There are a number of marshes, namely the Dankuni bil, the Makhalpara bil, the Bamandanga bil, the Ramnathpur bil, the Dingebhanga bil, the Churka bil, and they occupy depressions mainly between the two principal rivers mentioned earlier. The criss-cross channels are some evidences of a decaying distributary system, which are no longer capable of carrying much silt or water. Most of the marshes are without any outlet and whatever they had, have been interfered with by the erection of embankments to protect the roads and railways. Apart from these the general slope of the land is from northwest to southeast. These facts indicate an unequally aggraded area (1940). Bagchi (1944) regards this part as piedmont plain while Spate (1967) considers it to be a dead delta. From physical evidences the area resembles a moribund delta.

The Hooghly river, the most important river, contributes very little benefit to the area. It is a tidal river and with a large percentage of silt held in suspension creates the problems of flushing leading to silting up of the river, increasing salinity and blocking navigation. The Damodar, the other notable river, is notorious for its shifting course. It has the added disadvantage of having a wide catchment area, on impervious rock, which is channelled through a narrow course with sharp right angled bends. The recent river training through construction of dams and barrages, has accentuated the problem of drainage during excessive rains both in the catchment area and in the lower reaches. This is mainly due to the non-completion of the drainage scheme in the lower valley. These reservoirs have to release water at a time when the channels are filled with drainage water from neighbouring areas, which cause severe hardship to the locality. The river itself and its other courses are illsuited for drainage and unless these are excavated the problem will persist. The Mundeswari at present carries some amount of the Damodar water. Other streams of the area are, the Kana nadi, the Kana Damodar, the Saraswati, the Kaushiki, the Ghea and the Julka nadi. Except the Kana nadi others have no water supply from their head streams or take-off points. Nearly all the streams are meridional in alignment and flow in the north-south direction except the Kana nadi, the Ghea and the Julka. The Mete khal and the Dankuni drainage channel are the other drainage channels in this region.

There had been attempts at reclamation of the marshes and lowlying areas but they have proved failures. The embankments have accentuated the problem of drainage rather than solving it. The Damodar and other channels through which the flood waters drain whenever they overspill, which is quite frequent, they create water-logged areas. It is very difficult to drain them. Together with marshes it creates the problem of water logging. Hence in this area micro-relief is of importance from the agricultural point of view. The associated problem of drainage is important.

CLIMATE

Climatically, the area enjoys the same conditions as those prevailing in the Ganga Delta. Calcutta is representative of the conditions obtaining in this area. The normal mean winter temperature is around 19.5° centigrade and summer mean temperature is 32.2° centigrade. The annual mean rainfall indicates a decreasing trend towards the northwest. In the south around Chanditala the highest amount of rainfall occurs (1778 mm). The rainfall regime is identical in all the stations (Fig.-2), with concentrated rainfall during June to September. From agricultural point of view abundant heat is available throughout the year and abundant moisture is available during the months of June to September and nearly adequate in the months of May and October. The moisture deficiency is prevalent from November to April.

SOILS

This description of the soils of the area is based entirely on the data published by the Government of West Bengal (1965). The texture of the soils vary from sandy loam to clay but it is difficult to say with a certainty that they form homogeneous patches. On a very generalised basis it may be said that the areas near the Damodar river has sandy loam, while the land bordering the Hooghly levee has clayey loam to clay. The areas marked by marshes have some clayey soils and the soil profiles near them indicate poor drainage down the profile. On the whole except the areas mentioned, the profiles display good drainage conditions. The profiles in Chanditala P.S. and Tarakeswar P.S. display calcium carbonate concretions in their lower horizons which indicate a degree of maturity. It appears that the soils of this area are similar to the soils of Howrah district (1960). The low lying areas have hydromorphous meadow soil, while lepto-ferralitic soils are found in the areas of periodic flooding. The higher areas i.e., on the levee the soils are quasi-ferralitic with lime concretions. The soil reaction is on the acid side with neutral soils occuring in the eastern side. This too is a generalised picture. It may vary within the area. The nitrogen, phosphorous and potassium (N.P.K.) status of the soils are rather low. The organic matter content is also low, which is quite natural in a cultivated area. This indicates the necessity of applying fertilizers and composte manures for a good return in agricultural crops.

IRRIGATION

From the climatic conditions it is apparent that irrigation is a necessity for fuller utilisation of land and to meet the variable and uneven distribution of the monsoon. The irrigation map reveals that the canal irrigated lands are mainly confined to the area west of the Saraswati river. The area lying to the east are not only unirrigated but they suffer from the problem of excess water because of poor drainage. Within the later area the high lands are irrigated by tube wells. Prior to 1951 the source of irrigation water was mainly the tanks and by 1960-61 about 23 per cent of the total lands was brought under irrigation. This figure increased steadily to 32 per cent in 1965-66 and to 39 per cent in 1967-68 and it is estimated that by 1970-71 this will be 45 per cent of the total area. The Table-1 shows the nature of increase from 1965-66 to 1967-68 and also the amount of land under different irrigation systems. It is obvious that canal irrigation is by far the most important system followed

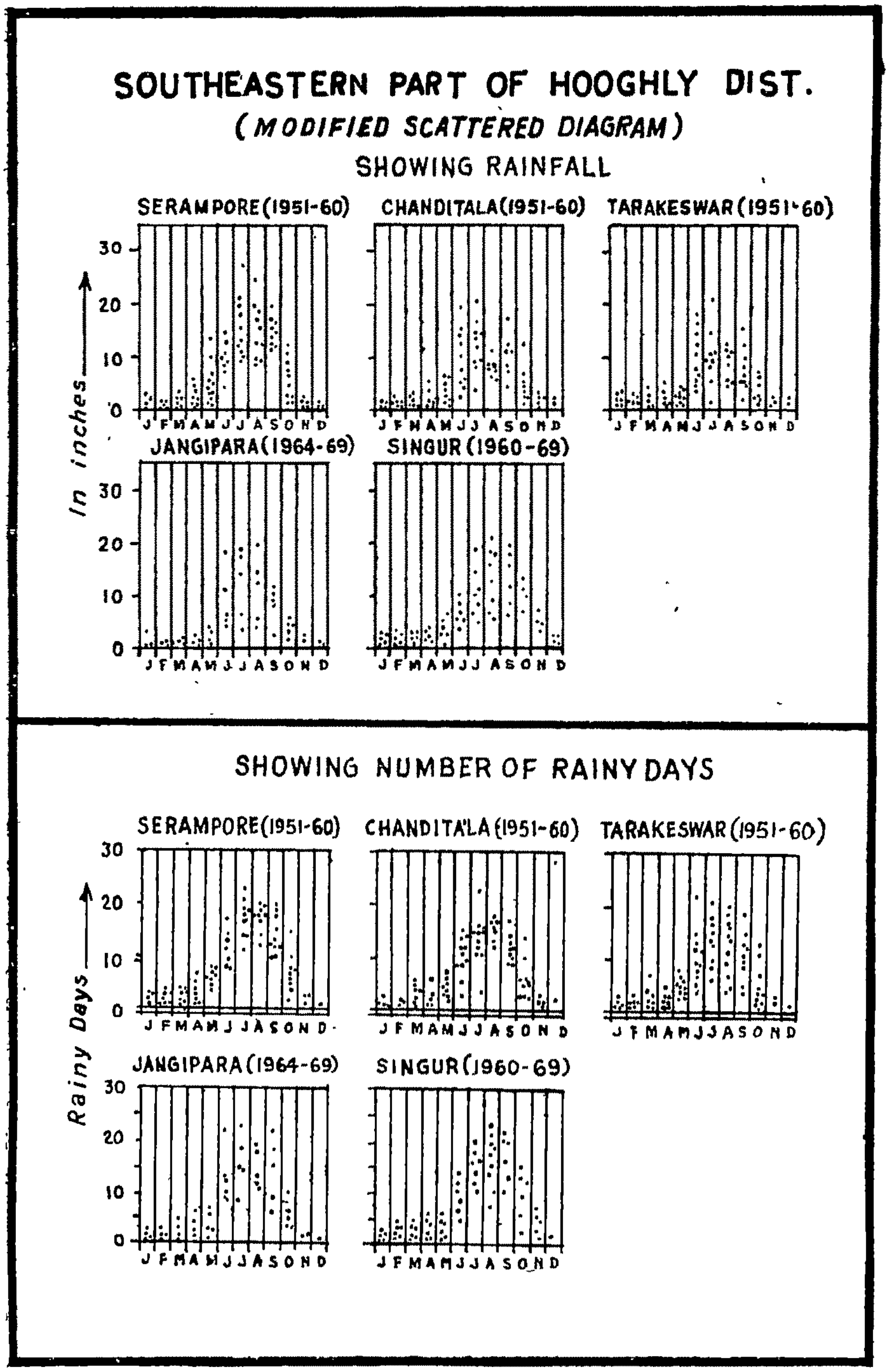

SOUTHEASTERN PART OF HOOGHLY DIST.
(MODIFIED SCATTERED DIAGRAM)
SHOWING RAINFALL
SERAMPORE(1951-60)
CHANDITALA(1951-60)
TARAKESWAR(1951-60)
JANGIPARA(1964-69)
SINGUR(1960-69)
In inches
0
10
20
30
J F M A M J J A S O N D
SHOWING NUMBER OF RAINY DAYS
SERAMPORE(1951-60)
CHANDITALA(1951-60)
TARAKESWAR(1951-60)
JANGIPARA(1964-69)
SINGUR(1960-69)
Rainy Days
0
10
20
30
J F M A M J J A S O N D

Fig. 2

by tanks, deep tube wells and shallow tube wells in order of decreasing importance. The areas irrigated by canal constitutes about 81 (1965-66) to 82 (1967-68) per cent of the irrigated land.

TABLE—1

Area in hectares and percentage of the total area

Year	Study Area	Total irrigated land		Irrigated by canal		Irrigated by Tube wells				Other Sources Mainly Tank	
						Deep		Shallow			
		Area	Percentage	Area	Percentage	Area	%	Area	%	Area	%
1965-66	91,555	29,533	32.3	23,974	26.2	...	...	...	...	5,559	6.1
1967-68	91,555	36,027	39.4	29,414	32.1	324	0.4	298	0.3	5,992	6.5

Canal

As stated earlier the portion west of the Saraswati river is well served by the canals and in most of the cases it follows the natural drainage lines, such as the Kana nadi, the Kana Damodar, and the Kausiki. These rivers generally dry up after the rains or there is so little flow that it is of no use. In Singur police station (thana) some of the minor streams are dammed up for irrigating *boro* paddy. The entire canal system within the *study area* forms part of the Damodar Valley Corporation's Eden Canal system. This system has remodelled the Kana Damodar, the Kana nadi and the Kausiki and a number of distributaries have been dug from these rivers. Table-2 reveals the nature of increase in irrigation facilities from 1963-64 to 1967-68. This also indicates that the Haripal thana has the largest amount of land under irrigation followed by Jangipara and Tarakeswar. These areas are also comparatively higher than the rest of the *study area*. The chief benefit from this system is the increased production of *aman* paddy and the resultant increase in the income of the farmers Among the draw-backs are the unsuitability of the canals to irrigate fragmented holdings, as this causes friction among the farmers and the fact that the crops not requiring water get damaged because of excess water. Inaccessibility of the distributary canal system is a draw back and poor maintenance causes silting. This difficulty is encountered in Tarakeswar police station. The irrigation tax appears to be high judging from the reaction of the farmers in the area. Some cases of misuse of the irrigation water is also observed, in the form of industries using it for non-agricultural purposes.

Tube wells : It is evident from Table-1 that tube wells are also a source of irrigation water but its role is minor. Both the types of tube wells are supplied by the local Block Development offices, but the farmers have to pay the cost. These are to be found in areas not covered by the canal system. There are three deep tube wells in the north west

TABLE—2

Distribution of Irrigated Areas and its Growth

Name of the Police Station	Area Irrigated during 1963-64 *in hectares*		Area Irrigated during 1965-66 *in hectares*		Area Irrigated during 1967-68 *in hectares*	
	Kharif	...	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Haripal	7,757.4	...	8,002.4	...	8,558.1	2,033.9
Singur	3,128.6	...	3,257.8	...	3,404.8	858.6
Tarakeswar	3,070.3	...	3,212.1	...	3,598.4	1,346.2
Jangipara	4,518.2	...	4,590.7	...	5,862.4	774.0
Chanditala	2,078.5	...	2,145.7	...	2,542.2	435.0
Total	20,533.0	...	21,208.7	...	23,965.9	5,447.7
Total Irrigated area in the 'Study Area'			29,533.0		36,027.0	

TABLE—3

Distribution of Tube Wells, Tube Well Irrigated Areas and Tank Irrigated areas (1967-68)

Name of the Block	Number of the Shallow Tube Wells	Number of the Deep Tube Wells	Area Irrigated by Shallow Tube Wells in hectares	Area Irrigated by Deep Tube Wells in hectares	Area Irrigated by Tanks in hectares
Tarakeswar	80	x	162	x	2,025
Haripal	3	x	6	x	648
Jangipara	20	x	41	x	810
Chanditala-I	17	x	34	x	...
Chanditala-II	18	x	37	x	608
Serampore and Uttarpara	9	x	18	x	522
Singur	x	3	x	324	1,379
Total	147	3	298	324	5,992

part of the Singur Block. They were sunk in 1965-66. A deep tube well can irrigate about 60-100 hectares, and costs about Rs. 125,000/- for installation. The depth of the tube well varies from 110-120 metres. These are diesel operated motors, hence not bound by availability of electricity. Apart from this there are

147 shallow tube wells within the *study area* and they are mainly concentrated in the Tarakeswar and Chanditala thanas. These are sunk to a depth of 24-79 metres, can irrigate 2-3 hectares of land, and costs about Rs. 6,000/- 7,000/- each for installation. These too, were introduced in 1965-66 in the Serampore and Uttarpara Block, and in the Singur Block seed farm. The introduction of high yielding variety of paddy and comparative cheapness in initial expenditure helped in its popularity. Table-3 gives an idea of the distribution of tube wells and the tank irrigation in the *study area.* This also shows that Tarkeswar and Singur have greater area under tube well and tank irrigation than other areas and they are placed third and fourth respectively in terms of area under canal irrigation. The initial enthusiasm of the farmers for shallow tube wells has waned because of its short period of effective usefulness, difficulties in repairing and maintaining the pumping set and the prohibitive cost in terms of its usefulness to the average farmers. The government subsidy for the shallow tube well is not a good enough encouragement.

Tanks : The second most important source of water apart from the canals is the tanks and it is the oldest source of irrigation. Cultivators who are out of the reach of canals and poor farmers in general utilise the tank. The Table-3 reveals its importance in areas out of reach from the canals (Tarakeswar—because of higher elevation) and in the east (Singur) where the network of canals is not well developed. For lifting water from the tanks the methods employed are traditional. They are *Siuni* (triangular bamboo basket), *Donga* (canoes, at present iron canoes are replacing the wooden variety), and the *Teri* (bucket and pole). With this method small areas can be irrigated and the amount of labour required is enormous. This is possible because of the excess labour force present in the agricultural field. At present some of the derelict tanks are excavated to store water for irrigation by this method. If power in the form of diesel or electricity is made available this source can irrigate more land cheaply.

COMMUNICATION

In the light of the above discussion of physical features, soils and irrigation let us examine the communication system of the *study area.* The transportation network appears to be largely influenced by the physical aspect and the economy of the area. Most of the early communication lines, both the roads and the railways, were peripheral in nature. The railway track runs through the comparatively higher lands. The railways have two types of gauges, the broad gauge—part of the Eastern Railway network, and the narrow gauge. (From the later part of 1970 this system is not working). Since 1958 all the broad gauge lines have been electrified. Both the system of railways carry much passengers and agricultural produce, particularly vegetables, such as potatoes, bananas, other seasonal vegetables and occasionally paddy. This latter produce is brought to Howrah maidan market and to the Calcutta market.

Most of the roads have been built since

the plan period and these roads actually, at present, covers much of the area. A rough calculation of railway track per square kilometre for the *study area* reveals a low figure (0 12 km/km^2) and if we do not consider the narrow gauge then the figure comes down to 0.99 km/km^2. In case of the roads it is 0 39 km/km^2 exclusive of municipal roads but taking into account all types of roads, i.e. metalled, unmetalled, district board and village roads. This figure rise to 0.82 km/km^2 if we include the municipal roads. The urban areas are mostly along the Hooghly side and the agricultural activity is confined to the rest of the area. With this fact in mind if we consider the road density or the road pattern for the area under study, it at once shows a dismal picture. It is indicative of the difficulties faced by the population, particularly in the rainy season.

POPULATION

As stated above, the Hooghly side is marked by the growth of towns, and it forms part of the Calcutta conurbation. This belt is marked by heavy concentration of population. Administratively, the police stations of Chandernagore, Serampore, Bhadreswar and Uttarpara form the predominantly urban areas. Other police stations having predominantly rural population are Chanditala, Haripal, Singur, Tarakeswar and Jangipara. The urban police stations contain the towns of Uttarpara, Kotrang, Konnagar, Rishra, Nabagram Colony, Serampore, Baidyabati, Champdani, Bhadreswar, and Chandernagar, while Singur and Tárakeswar towns fall within the rural police stations. A calculation of percentage of rural population to the total population shows cent per cent rural population in the police stations of Chanditala, Jangipara and Haripal and for Singur and Tarakeswar the figures are 93.84 and 89.94 percent respectively. For the urban police stations the figures are, Uttarpara (19.32), Bhadreswar (18.95), Serampore (11.64), per cent. Only Chandernagar has cent per cent urban population.

The Table-4 indicates police station-wise the nature of population density changes from 1941 to 1961, total population, the rural population, percentage of rural population and percentage of workers engaged in cultivation. This clearly indicates the agricultural nature of five police stations described as rural. The Hooghly side may be described as dynamic region (Sen Gupta and Sdasyuk, 1968) and a powerful magnet attracting rural population because of unparalleled concentration of industries in this belt. For the present study this belt is only important for its effect on the adjoining areas and we are more concerned with the rural police stations to study the agricultural changes. These also show a gradual increase of pressure on land.

AGRICULTURE AND LAND-USE

From the foregoing portion we can form an idea about the physical and other allied conditions, e.g., irrigation facilities, communication, population that influence the agriculture of this *study area*. The Table-5 indicates the land-use changes from 1944-45 to 1967-68. It is worth mentioning that in this area the following crop rotation pattern is practised.

TABLE—4

Police Stations	Density of Population/km²			Population (1961)		Percentage of	
	1941	1951	1961	Total	Rural	Rural Population to Total	Workers engaged in Cultivation
Chandernagar	3,963	5,166	6,946	67,105	...	0. 0	0.20
Serampore	2,236	2,432	3,401	197,345	22,977	11.63	6.22
Bhadreswar	1,756	2,025	2,401	95,769	18,151	18.95	6.35
Uttarpara	1,193	2,265	3,865	112,138	21,666	19.32	2.60
Chanditala	754	789	1,021	166,884	166,884	100 00	48.23
Singur	562	650	873	128,574	120,659	93.84	63.08
Tarakeswar	440	512	707	84,778	76,250	89.94	67.17
Jangipara	409	436	591	96,944	96,944	100.00	61.80
Haripal	399	457	607	111,823	111,823	100.00	74.86

a) Jute—Potato/Onion and other Vegetables.

b) *aman* Paddy—Gram—Summer Vegetables.

c) *aus*—Wheat—Summer Vegetables.

Among the crops cultivated mention may be made of sugar cane, oil seeds, pulses, *boro* paddy, and high yielding variety of paddy, apart from those mentioned previously with the crop rotation pattern. Sengupta and Sdasyuk (1968) mention this area as having the crop combination of rice, gram and jute, which is quite apparent from the crop rotation pattern. The table-6 also indicates the nature of the changes in the cropping pattern in

TABLE—5

Land Use	1944-45*		1954-57		1967-68**	
	Area in hectares	Percentage of Total	Area in hectares	Percentage of Total	Area in hectares	Percentage of Total
Net Cropped Area	68,930	76.1	67,356	73.9	65,246	76.7
Double Cropped Area	8,196		11,765		27,648	
Current Fallow	458	0.5	347	0.4		
Net Unculturable Area	17,194	19.0	18,114	19.9	1,992	23.3
Net Culturable Wasteland	4,085	4.4	5,271	5.8		
Total Area	90,670	100.0	91,091	100.0	67,238	100.0

* Excluding Chandernagar Police Station.

** Excluding Municipal Areas of about 24,317 hectares.

general that has occurred between 1944-45 and 1967-68.

Sample study :

Now instead of studying the area in a generalised manner, it will be better to study the agricultural changes at the village level. For the purpose twelve villages have been studied (Fig-3). The criteria of selecting the villages were the nature of drainage, availability or non-availability of irrigation facility, accessibility and distance from urban areas.

The land-use of the villages was mapped plot by plot in the cadastral map. In some instances help of the local gram sevak was enlisted. The five mouzas of the Singur police station were studied in detail, while for other mouzas such detailed information not collected. Field observation was undertaken during the period—middle of December 1968 to end of January 1969. The land of each mouza (village) has been classified into four categories and they include the areas as shown in the following pages.

TABLE—6

Area in hectares

Crops Cultivated	1944-45	1954-57	1967-68**
Total Cropped Area	77,126	79,121	97,405
Total Paddy Area	50,315	47,716	62,698
Aman Paddy	46,893	N.A.	46,759
Aus Paddy	3,418	N A.	8,370
Boro Paddy	4	N.A.	1,873
High Yielding Paddy	00	00	5,696
Wheat	13	5	1,447
Jute	5,304	11,113	10,432
Vegetables	3,172	1,110	2,408
Pulses	2,550	5,941	1,467
Potatoes	5,378	6,527	7,200
Sugar Cane	706	73	160
Oil Seeds	76	10	333
Orchards*	7,161	6,588	3,415
Miscellaneous Crops	000	000	7,837

* Orchards include mostly the banana plantations and other fruit-gardens such as Mango, Jackfruit, Pineapple, Custard apple, Coconut, and Water Melon fields. ** Data collected during Field-work.

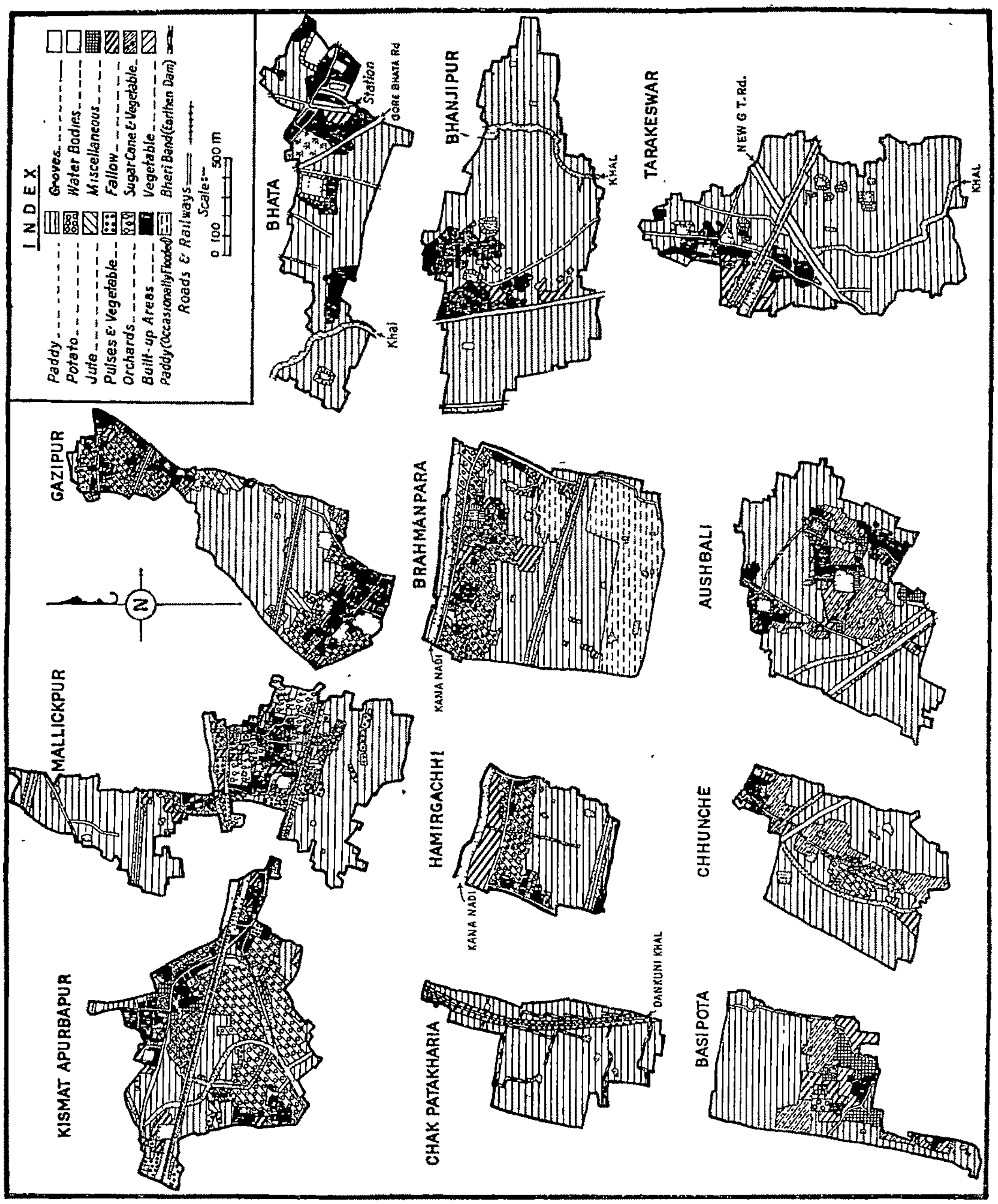


Fig. 3

A) *Cultivated*: Agricultural land excluding garden crops, but including all types of crop land like, *aman*, *aus*, jute, potatoes, vegetables, onions, gingers, turmerics.

B) *Cultivable* : (i) Groves and Jungle

—bamboo groves, thickets are included in this category. (ii) Orchards—mango groves, banana plantations and other such fruit gardens are included in this category.

C) *Non-Cultivated*: (i) Residential—this includes homestead land, school, libraries (including any public building), farm houses. shops, and other service centres. (ii) Roads and Railways—including metalled, unmetalled roads, lanes and by-lanes. (iii) Water-bodies—includes tanks, rivers, canals, and wells.

D) *Miscellaneous*: Danga land (highland), raised banks of the tanks, bunds, cremation grounds, temples, and *bhagar* (a place for carcasses).

Besides, this, in Singur police station the land has also been classified on the basis of drainage. The categories are :

1. Relatively Higher Land—Well drained and dry.
2. Moderately High Land—Less well drained and dry.
3. High Land—Medium drained and moist.
4. Relatively Low land—Not so well drained and very moist.
5. Low Land—Poorly drained and wet.

The term high, low are used in the comparative sense. Agriculturally the year can be divided into two seasons, the *kharif* season and the *rabi* season. The *kharif* crops are sown from May to September and harvested from September to December. The *rabi* crops are sown from October to November and harvested from December to February.

The villages are described from west to east, physically from highland to low land of the *study area* From irrigation point of view, it is from irrigated area to non-irrigated area, and agriculturally, from predominantly rural area to urban area.

Bhata :

This mouza or village lies in the western fringe of the Tarakeswar town. It presents two contrasting cultural landscapes. On the eastern side of the Gore-Bhata road, which runs through this mouza, one finds the urban portion of Bhata while in the western portion lies the rural settlements. This mouza has an area of 97.7 hectares with a population of 2,700 (1961) approximately. About 83 hectares or 80 percent of the land is devoted to cultivation and the rest is occupied by settlements. The cultivated land is low-lying while the relatively higher land is occupied by settlements.

Aman paddy occupies about 65 hectares of land and it is generally the low-lying tracts that are devoted to this crop. This also helps to hold water for the *aman* paddy. After the harvest of the paddy winter vegetables and *rabi* crops are raised on the same land. The winter vegetables are predominantly corriender and brinjals. The *rabi* crops are mustard and pigeon pea (*arahars*) mainly. The average yield of paddy is 11 quintals per hectare. The highest yield in some favourable years may reach 18 quintals per hectare. The farmers use chemical fertilisers for paddy cultivation, the amount being 2.6 to 5.6 quintals per hectare.

The higher lands separated from the low-lying paddy fields by low embankments are devoted to jute cultivation. The land is occupied by jute, including the preparation of land, from April to September and subsequently kept fallow for one month. Then the land is prepared for potato cultivation. After the potato is harvested, sometimes the same land is utilised for spring vegetables otherwise it is kept fallow. With the advent of the nor'wester season the land is prepared for jute cultivation and the cycle of cultivation starts again. About 18 hectares of the total area is devoted to jute cultivation. The yield of potato is about 282 to 333 quintals per hectare. The amount of chemical fertilisers needed and used varies between 19 to 22 quintals per hectare.

Canal irrigation water is obtained from D/1 canal. The area irrigated by it has remained constant from 1963-64 to 1967-68, 11.3 hectares for the *kharif* season. The tanks within the mouza are used in some areas for retting the jute and in others for irrigation purposes. The tanks situated in the northeastern part of the mouza is utilised for retting while, the tanks in other areas are utilised in winter months for irrigation. The method of water lifting is labour intensive with a little mechanical aid, mainly by canoe-shaped wooden vessels. The *khals* also provide some irrigation water in winter months. They remain dry during the summer months.

Rest of the mouza, about 20 per cent of the area, is used for settlement purposes. Some of the tanks have been newly excavated and around them new settlements have sprung. This area was previously utilised as cremation ground. The new settlers are mostly from East Bengal. The older settlements are amidst the cultivated fields in the western side of the mouza. The older residential areas have mud built houses, while the newer residential areas have houses of even less durable materials.

Bhanjipur :

Bhanjipur mouza lies to the north of Tarakeswar mouza in the Tarakeswar police saction, with an area of about 122.4 hectares. There are about 237 families with a total population of 1,563 (1961). The agricultural nature of the village is evident as one enters the village from the south. The north-central part of the mouza is residential and barring a small patch in the north which is fallow, the rest of the land is cultivated.

The cultivated land accounts for 69 per cent of the mouza or 85 hectares. Paddy (*aman*) is the chief crop with 40.5 hectares of land, while jute and potato account for 20.2 and 19.4 hectares respectively. Other crops are *aus* (0.8 hectares), sugarcane (0.4 hectares) and wheat (0.4 hectares). Paddy lands remain fallow after the harvest of *aman* paddy, while the jute lands, which are situated at a slightly higher level, are utilised for growing potatoes during winter season. Paddy and jute are non-irrigated crops. A few active farmers cultivate vegetables in the fields adjoining their cottages or along the tanks near their homestead land.

The same D/l canal and some big tanks provide the irrigation water. A drainage *khal* runs through the cultivated fields in the east of the mouza. The amount of land irrigated by the canal has remained same since 1963-64 to 1967-68 in the *kharif* season. The homestead lands are generally higher and are at the same level as the roads. The economic condition of the cultivators is good compared with the other mouzas described so far. In this mouza there are no landless (agricultural) labourer, and the farmers own neat farmhouses and bullocks and other farming implements. This village is nearly self-sufficient except for a market.

In the total working population of 433 (1961), 203 are cultivators. 41 persons are engaged in manufacturing, 26 in trade and commerce and 7 in other services. It is to be noted that among 237 families 203 persons are cultivators.

Tarkeswar :

This mouza is bounded in the north, south and east by the cultivated fields of Bhanjipur, Bhimpur and Bajitpur respectively and in the west the urbanised areas of Bhata mouza, lies a part of the Tarakeswar town. Tarakeswar is a religious centre and at present it is a growing township with rapidly developing localities. It has a daily market and its importance is increasing with the opening of the new Grand Trunk road and electrification of the railways. Roner *khal* is the main drainage channel of the area. Drainage is the main problem of the settlement and the cultivated land and it has yet to be solved satisfactorily. It has an area of about 153 hectares.

From the land-use aspect the mouza can be divided into two segments, the built-up section and the cultivated land. The built-up section is mainly in the northern part of the mouza, with some cultivated land. From field investigation it was gathered that much of the built-up area has encroached upon the agricultural land in the recent development of the town. If the present rate is maintained, in the coming decade the area lying to the north of the new G. T. road may be fully built-up.

The cultivated land, about 106 hectares, lies mostly to the south of the new G. T. road. As in the previously described mouza, the low-lying areas are devoted to *aman* paddy cultivation (76 hectares) and the comparatively higher lands are devoted to jute (28.7 hectares) and potatoes (28.3 hectares). The jute growing lands are double cropped, potato being the second crop. *Aus* paddy and wheat are the other crops of minor importance.

The Kana Damodar provided the irrigation water though to a very small area, 3.2 hectares in 1963-64 and 2.4 hectares subsequently from 1964-65 to 1967-68 during the *kharif* season. Farm holdings are small, farming methods are primitive and traditional. A recent development is the introduction of *bóro* paddy cultivation. This is still in the experimental stage and the area is small. The farmers use the ready made mixed chemical fertilisers obtainable from the Tarakeswar market. But about 20 per cent farmers use oil cakes as fertilisers.

The farmers' homesteads are situated in

the south along the unmetalled road, which is relatively on a higher land and it prevents the occasional inundations. The farmers' houses are built up of mud while the urban sector has brick-built houses.

Brahmanpara :

This mouza is located on the right bank of the Kana nadi, which flows through the extreme north of the village in a east-west direction, within the Haripal police station, with an area of 109.4 hectares. The metalled road from Baidyabati to Tarakeswar runs through the mouza, and an unmetalled road passes through the extreme north of the mouza. The Haripal railway station is about 5 kilometres away from the village towards the north.

The following table indicates the land-use of the mouza :

Land Use	Area in hectares	
A. Cultivated		93.5
Aman	76.1	
Others	17.4	
B. Cultivable		4.5
Danga	3.6	
Orchards	0.9	
C. Non-cultivated		9.9
Residential	4.4	
Roads and Railways	2.1	
Water bodies	3.4	
D. Miscellaneous		1.5

It is evident from the above that *aman* paddy land forms the bulk of the cultivated land and it is mainly in the southern portion of the mouza. The land nearer the Kana nadi is devoted to the cultivation of sugarcane, jute, vegetables, pulses and banana plantations. These lands are generally higher, and are devoted to double cropping and the Kana nadi supplies the water for irrigation. The crop rotation in the double cropped land is jute-vegetables or jute-pulses/potatoes. The following table shows the area irrigated by the Kana nadi.

Years	Area in hectares	
	Rabi	*Kharif*
1963-64	11.3	58.7
1964-65	11.7	58.7
1965-66	12.9	58.7
1966-67	12.9	58.7
1967-68	15.8	58.7

Most of the settlements are in the northern part of the mouza, a high land area. Of the total population of 504 (1961), 74 persons are cultivators, 66 persons are agricultural labourers and 40 persons are engaged in manufacturing, trade and commerce etc. and 324 persons are non-workers.

Hamirgachhi :

This mouza is located to the east of the Brahmanpara mouza on the right bank of the Kana nadi and it has the same characteristics of physical layout as the neighbouring village. The only difference is the presence of sandy bank on the Kana nadi, in the northern part of the mouza, a fallow land. The total area of the mouza is 41.4 hectares. The road from Baidyabati to Tarakeswar passes through the northern part. The total population is 185 (1961). The following reveals the land-use of the mouza.

Land-use	Area in hectares	
A. Cultivated		29.5
Aman	21.6	
Others	7.9	
B. Cultivable		7.4
Danga	6.9	
Orchards	0.5	
C. Non-cultivable		4.0
Residential	1.9	
Roads and Railways	0.9	
Water Bodies	1.2	
D. Miscellaneous		0.5

The table reveals that *aman* paddy land forms the bulk of the cultivated land. This type of land lies mostly in the southern part of the village. In the higher lands the crops cultivated are potato, jute, cauliflowers, pulses and other vegetables. These are the lands devoted to double cropping. The farmers use mainly fertilisers like the urea and ammonium sulphate, and organic manures like cow-dung, oil-cakes and pond mud. They also use irrigation water which is provided mainly by the Kana nadi. A small canal dug from the river also provides the irrigation water. The following table shows the amount of land irrigated in *kharif* and *rabi* seasons.

Years	Area in hectares	
	Rabi	*Kharif*
1963-64	10.9	10.5
1964-65	11.7	10.5
1965 66	12.5	10.5
1966-67	12.5	10.5
1667-68	12.5	10 5

Though the homestead lands are generally in the higher land, the settlements are scattered in the northern region. Among the total workers numbering 42 (1961) cultivators (20) and agricultural workers (17) form the bulk and the rest are engaged in other occupations. Non-workers number 143.

Chhunche :

This mouza lying within Chanditala police station is closely connected with the semi-urbanised village of Mosat. This mouza is well served by roads, railway and canals. Old Benaras road and Howrah-Sheakhala light railway run parallel to each other through the northern half of the mouza. Damodar Valley Corporation's distributary canals K/1 and K/1A pass through the cultivated land. The total area of the village is 62.4 hectares.

The following table reveals the land-use pattern of the mouza.

Land-Use		Area in hectares
A. Cultivated		45.7
Aman	37.4	
Others	8.3	
B. Cultivable		1.4
Danga	1.4	
C. Non-cultivable		13.5
Residential	6.7	
Roads and Railways	3.2	
Water bodies	3.6	
D. Miscellaneous		1.8

As in the previous descriptions the paddy land accounts for the major cultivated tract. The higher lands in the rest of the area grow sugarcane, vegetables and jute and they are the lands given over to double cropping. Recently the *aman* lands are also used for the double cropping purposes and the land under double crops amounts to 18.4 hectares. The rotation pattern is jute-vegetables/pulses. The farmers use both the varieties of fertilisers i.e. the organic and inorganic. The inorganic fertilisers used are urea, ammonium sulphate, super phosphate and muriate of potash. The farm yard manures, cow-dung, oil cakes etc are the organic manures used. Vegetables are the main commercial crop which are sent to the markets of Mosat, Chanditala and to Howrah, mainly by train. The irrigation water is provided by the canals K/1 and K/1A. Since 1963-64 to 1967-68 the area irrigated by the canal has remained constant, i.e, 22.2 hectares and that too mainly in the *kharif* season.

There are mainly two compact settlement areas. The mouza has 865 persons (1961) of which total workers are 221 and non-workers are 644. Cultivators (86) and agricultural workers (74) are the most important groups followed by persons engaged in trade and commerce (32) and the rest are occupied in sundry other occupations, like transport, manufacturing, house-hold industries etc.

Ausbali :

This mouza too is very near to the Mosat village and lies to the north of Chhunche, in the Chanditala police station. In this mouza roads, railway and canal are present and like the previous mouza the Old Benaras road and light railway run parallel to each other in the southern sector of the mouza. The K/1 canal of the previous mouza runs through the village. The total area of the mouza is 92.6 hectares.

The land-use pattern of the mouza is revealed by the following table.

Land-Use	Area in hectares	
A. Cultivated		65.7
Aman	54.9	
Others	10.8	
B. Cultivable		3.7
Jungle	0 9	
Orchards	2.8	
C. Non-cultivable		21.0
Residential	11.7	
Roads and Railways	2.3	
Water bodies	7 0	
D. Miscellaneous		2.2

The above gives the same picture as in other mouzas described so far. The *aman* paddy lands are preponderent. The higher lands account for sugarcane, jute, pulses and vegetables. These are the lands devoted to double cropping. The crop rotation is jute-vegetables/pulses. The farmers use inorganic fertilisers like urea, ammonium sulphate, super phosphate and muriate of potash. The organic manures are cow-dung, oil cakes and green manures. Agricultural methods are primitive though some modern implements are used. The irrigation water is provided by K/1 canal of the Damodar Valley Corporation and the land irrigated in *kharif* season was 25 hectares in three successive seasons of 1963-64, '64-65, and '65-66, which rose to 25.4 hectares in 1966-67 and to 31.6 in 1967-68 Paddy and vegetables are the surplus products sent to the market of Mosat, and even to Howrah by train.

There are 932 persons (1961) of which 674 are non-workers and cultivators (87) and agricultural workers (83) account for the largest group of workers among 258, and the rest are engaged in trade and commerce, manufacturing and other services.

Kismat-Apurbapur :

The village Kismat-Apurbapur is situated within the Singur police station with an area of about 92.1 hectares. To the north-east lies the mouza of Gazipur and in the south-west lies the Burigaon. The Tarakeswar branch line of Eastern Railway runs right through the village. Damodar Valley Corporation's N/3 canal passes through the western part of the village in a zig-zag course. A road from Baidyabati enters the mouza and bifurcates one of the off-shoot, runs parallel to railway line and the other runs towards the south to Mosat village. The homestead land is not in one locality but it is distributed throughout the village. The following table indicates the land-use pattern of the village.

	Land-use	Area in hectares	
A.	Cultivated		55.9
	Aman	21.0	
	Jute and others	34 9	
B	Cultivable		0.8
	Jungle	0.1	
	Orchards	0.7	
C.	Non-cultivable		32.6
	Residential	9.4	
	Roads and Railways	6.0	
	Water bodies	17.2	
D.	Miscellaneous		2.8

On the basis of drainage the mouza has been sub-divided into :

	Types of Land	Area in hectares
1.	Relatively higher land	15.8
2.	Moderately high land	2.5
3.	High land	35.6
4.	Relatively low land	21.0
5.	Low land	17.2

A comparative study of the tables reveals that *aman* land is relatively low land, and relatively higher land and the moderately high land includes the residential area, roads, raised tank banks etc. Jute land and orchards occupy the high land. The jute land is double cropped, the other crops are potatoes and pulses. About 99.12 per cent of land holdings are less than 0.4 hectares in size, while only 8 plots are greater than 0.4 and less than 0.8 hectares in size. This shows the fragmentation of the land. The crops of main importance are the jute, followed by potatoes, *aman* paddy, pulses and *aus* paddy in descending order. Crop combinations are as in the earlier village : jute-potatoes/pulses. The only significant feature is the predominance of jute. The double-cropped land accounts for 34.3 hectares, a major part of the cultivated area. A look in the map will show that much of the area is devoted to jute cultivation. The main reason for the jute's popularity is the high yield and the consequent high return from the land. Most of the jute and potatoes are moved out of the area to Sheoraphuli market. This shows the importance of the cash crop and partly the commercialisation of the agriculture.

The double cropped land is irrigated by Damodar Valley Corporation's N/3 canal and by diesel pumps. The N/3 canal traverses the village from north to south. There are also some distributary canals which supply water to remoter fields. There are also some tanks which irrigate the land and have been recently dug. From 1963-64 to 1965-66 the area irrigated during *kharif* season was 20.6 hectares. During 1966-67 the area increased to 21.0 hectares and subsequently to 23.1 hectares in the following year. From 1966-67 *rabi* season irrigation also started and the figure was 8.1 and it increased to 9.7 hectares in the following year. These figures relate to N/3 canal.

The total population of the village is 1004 (1961) and the people are engaged in both agriculture and other services.

Gazipur :

This village is also situated in Singur police station, adjacent to the previously described village. It is well served by roads. It has an area of 77.6 hectares. It is connected with Singur, Gopalnagar and Benipur. On the basis of landuse the village can be divided into three parts, (i) the northern parts lying north of the Damodar Valley Corporation's N/5 canal is occupied by residential area, water bodies and high lands, (ii) the middle portion lying between N/5 canal and the metalled road is devoted to paddy fields mainly, and (iii) the southern part having similar land-use as the northern part.

The following table indicates the land-use pattern of the village.

Land-Use	Area in hectares	
A, Cultivated		51.9
Aman	35.5	
Jute and others	16.4	
B. Cultivable		Nil
C. Non-Cultivable		21.7
Residential	11.8	
Roads and Railways	1.9	
Water bodies	8.0	
D, Miscellaneous		4.0

On the basis of drainage the land in the mouza has been sub-divided into the following categories.

Types of Land	Area in hectares
1. Relatively higher land	13.8
2. Moderately high land	3.9
3. High land	16.4
4. Relatively low land	35.5
5. Low land	8.0

A comparative study of the tables indicates the type of land devoted to different land-uses, e.g. water bodies are low land, *aman* paddy land is relatively low land, relatively higher land is devoted to residential uses and roads. Jute land is double cropped and it occupies high land. The fragmentation of land is of same order as in other Singur villages (99.9 per cent of the plots are less than 0.4 hectares in size). The crops cultivated are paddy, jute and potato. Potato is cultivated in the jute lands.

The irrigation water is obtained from the Damodar Valley Corporation's N/5 canal, mainly in the north, while in the south water is obtained from the tanks. The irrigated area by the canal has remained constant 29.1 hectares from 1963-64 to 1967-68 for the *kharif* season, while for the *rabi* season the figure is 2.4 hectares for 1966-67 and 1967-68.

The total population of the village is 1368 (1961). The populated parts are in the north and in the south, the northern portion is occupied mainly by cultivators.

Mallickpur :

This village is situated within the Singur police station and quite well served by roads and has an area of 95.8 hectares. In this village the settlement and orchards occupy the central position, while the cultivated land lies to the north and south. The settlements are slowly encroaching into the cultivated fields near the railway tracks.

The following table indicates the land-use pattern of the village.

Land-Use	Area in hectares	
A. Cultivated		65.4
Aman	55.0	
Jute and others	10.4	
B. Cultivable		10.9
Jungle and Danga	3.1	
Orchards	7.8	
C. Non-Cultivable		16.9
Residential	5.6	
Roads and Railways	1.0	
Water bodies	10.3	
D. Miscellaneous		2.6

On the basis of drainage the land in the mouza has been sub-divided into the following categories.

	Types of Land	Area in hectares
1.	Relatively higher land	6.8
2.	Moderately high land	5.2
3,	High land	18.5
4.	Relatively low land	55.0
5.	Low land	10.3

A comparative study of the tables indicate the same picture as pointed out for the other villages. The low land is occupied by water bodies, *aman* paddy land occupying the next higher category, the residential area and the communication lines occupying the first category of the land. The fragmentation of the land is high, 97.3 per cent of the plots are less then 0.4 hectares in size, only two plots are between 1.2 to 0.8 hectares in size. The crops cultivated in order of area are *aman* paddy, jute, potato, pulses, and *aus* paddy. Crop combination is jute-potato or jute-pulses. Double cropped land amounts to 8.5 hectares. The cultivators use both organic manures and inorganic manures. A greater variety of crops are cultivated possibly due to the nearness of the Singur market (about 1.6 kilometres away).

The Damodar Valley Corporation's canal N/5 provides the irrigation facility and also the tanks provide some water. An interesting feature of the canal irrigation is the decline of area from 9.3 hectares (1963-64, 1964-65) to 7.7 hectares, (1965-66 to 1967-68), during the *kharif* season. There is no *rabi* irrigation from the canal. This does not show the exact picture, the canal runs through the northern part and the irrigation requirement is acute.

This village has a population of 517 (1961) and most of them are cultivators.

Chak-Patakharia :

This village is within the Serampore police station and is located near the Dankuni marshy tract. The Dankuni drainage channel flows through the eastern side of the mouza. Nearly the entire village is low-lying area. Generally, the land is flooded during the rainy season, hence cultivation is not possible. The people catch fish in their flooded paddy fields. During the dry months the cultivators cultivate vegetables on both sides of the banks of the Dankuni channel. The water is obtained from the channel by indigenous methods. In the years of low rainfall or evenly distributed rainfall the land yields a good paddy crop. For this the cultivators sow their land in April-May, but the crop depends on the nature of rainfall. The village has an area of 45.5 hectares, most of which is cultivable. A small amount of land is under tanks.

Basipota :

This village is also situated near the Dankuni marshes, but it is within the Uttarpara police station. Though it is very near urbanised area it is not so well communicated. It has an area of 55.4 hectares, with about 1/5th of the area under cultivable waste land. The following table gives the land-use pattern of the village.

	Land-Use	Area in hectares	
A.	Cultivated		39.6
	Aman	32 3	
	Jute and others	7.3	
B.	Cultivable		10.7
	Jungle and Danga	9.7	
	Orchards	1.0	

C. Non-Cultivable		4.1
Residential	2.5	
Roads and Railways	0.6	
Water bodies	1.0	
D. Miscellaneous		1.0

Settlements are scattered over the mouza. There is no *aus* cultivation, and other than jute, sugarcane and vegetables are also cultivated. Double cropped area is small. The high amount of culturable waste is due to the concentration of bamboo groves, jungles and orchards. All the crops are locally consumed, though some vegatables are sold in the nearby market of Raghunathpur. The farmers use artificial fertilisers, available from the nearby urban areas

The population of the village is 285 (1961) of which cultivators and agricultural workers account for 78 persons and rest of workers 50 are engaged in house hold industries and commerce. Non-workers number 158.

DISCUSSION

The previous description shows that the dynamic aspect of agriculture in the different mouzas, thanas and blocks is based on the changing economic activity. It is also clear from the general description of the agriculture and land-use of the *study area* that since partition the demand for jute has caused the increase of jute area. This was partly facilitated by the new settler agriculturists, who are familiar with jute cultivation. They also partly introduced the use of fertilisers. There are indications of slow extension of irrigation facilities, improved techniques of cultivation and improvements in marketing facilities.

Inspite of these changes the agriculture of this area has been primarily dependent on the natural phenomenon. The nature of the landscape, the levees and the man-made bunds have created the drainage problem. The portions adjoining the Hooghly levee are urbanised, and are generally of little agricultural importance. The more one moves towards the west the more agriculture becomes the primary occupation.

Of the twelve mouzas studied, only in two villages irrigation is not practised and there the occupation is not primarily agricultural. The other ten villages are not only irrigated but they also indicate influence from the urban areas. From the aspect of implements, the village study shows that the farmers are aware of new or improved implements, though the villages are not always well communicated. Nevertheless they are within the influence of urbanised settlements of Singur and Tarakeswar. The demonstration farm at Singur has influenced the farmers and some of the farmers have tried to follow the methods. It was also noticed that organic fertilisers are almost universally used but the inorganic fertilisers are used by the mouzas nearer the urban area or Block Development Office. These aspects show that the reception to new ideas is conditioned by the nearness to urban areas and also availability of technical know-how. The restrictive influence of financial solvency is also operative.

Better quality seeds are necessary for increasing the total yield and the farmers are eagar to use improved seeds (high-yielding paddy). At present, the Block Seed Farms supply better quality seeds at cheaper rates, but the quantity is negligible, and there are only two Block Seed Farms in the *study area.* They could not cater to the demand. Irrigation facilities are available in the form of canal and shallow tube-wells. At present there is a greater demand for irrigation facilities but the facilities are not keeping pace with the demand. This also shows that farmers are ready to use the better facilities but are hampered by the high rate of water tax and the non-availability of irrigation acts as check on their greater utilisation. Eight out of the twelve mouzas are illcommunicated. This creates the problem of disposing off the surplus produce. If these mouzas were well communicated greater movement of the surplus products would have been to the markets and a resultant greater commercialisation of agriculture.

An impediment to the better agricultural out-put is the fragmentation of holdings and the extortionate rate of interest of the village money lenders, which cripple the farmers.

The comparative ffgures of the area under different crops in the *study area* reveal that there is an increase in the total cropped area. It is spectacular in case of *aus*, *boro*, high yielding paddy and wheat. This has been possible because of irrigation, fertilisers and improved seeds. The area under *aman* crop has remained constant. Probably the land suitable for *aman* crop is utilised to the maximum capacity. Though it has increased the jute area shows fluctuations. This is mainly due to flood and fluctuating prices. The area under potato has increased mainly due to the growth of cold storage facilities, and also due to the price rise, but it also shows fluctuations clearly a case of market influence. In recent years it has been affected by disease. Oil seeds, tobacco, betel leaf, maize, garlic etc shows an increase which is caused by the better facilities of irrigation and greater demand. Pulses and vegetables show a decreasing pattern and these lands have either been devoted to high-yielding paddy or to potato, a case of greater net return from land and other investment. The decrease in the area under orchards is accounted for by the increasing demand for settlement areas caused by increasing population and influx of population.

Conclusion

In conclusion it may be said that the drainage problem in the eastern part of the *study area* is acute. The demand for more irrigation facilities, better seeds, and implements are present. Farmers are responsive to new methods. Communication system needs improvement. Inspite of these the agriculture of the *study area* has improved, mainly because of increasing availability of irrigation facility and its utilisation, improved seeds, better farming methods, double and multiple cropping of the land and the greater demand created by growth and influx of population. Still old methods and practices of cultivation persist.

Apart from economic aspects of improvement the following lines of improvement are suggested :

(i) Animal husbandry on scientific lines, (ii) agro-based industries to absorb the excess population, (iii) expertise on soil and its management to be made available locally, (iv) improved lines of communication and (v) more demonstration farms to disseminate improved agricultural techniques.

REFERENCES

Bagchi, K. (1944) : *The Ganges Delta,* Calcutta University Press, Calcutta, 157 p.

Chatterjee, S. P., Lahiri, R. and Mukherjee, S. N. (1960) : *Classification of Alluvial Soils of Howrah, West Bengal,* Geographical Review of India, Vol. 22 (iii) Calcutta.

Government of West Bengal (1961) : *Statistical Abstract of W. Bengal,* W. Bengal Government Press, Alipur.

Government of West Bengal (1965) : *Classification, Composition and Description of Soil Profiles of West Bengal, Technical Bulletion No. 6,* W. Bengal Government Press, Alipur.

Mitra, A., (1953) : *An account of Land Management in W. Bengal 1870-1950,* W. Bengal Press, Alipur.

Sen, C. (1947) : *Agricultural Statistics by Plot to Plot Enumeration, 1944-45,* conducted by H. S. M. Ishaque, Part III Union Tables, Bengal Government Press, Alipur.

Sen Gupta, P. and Sdasyuk, G. (1968) : *Economic Regionalization of India, Problems and Approaches,* Census of India, 1961, Monograph No. 8, New Delhi.

Spate, O. H. K., (1967) : *India and Pakistan, A General and Regional Geography,* Methuen, London.

Strickland, C., (1940) : *Deltaic Formations,* Longmans, Calcutta.

West Bengal Census (1951) : *Census Handbook of Hooghly,* W. Bengal Government Press, Alipur.

do (1961) : *do* , do , Alipur.

AN APPROACH TO LAND CLASSIFICATION IN DWARKA-BRAHMANI CATCHMENT AREA, DIST. BIRBHUM.

PIJUSH K. SAHA

Abstract

In any field of study classification is really a complicated practical job. Difficulties are faced in delineating the limits for different groups and sub-groups. Object of classification would always be more definite and clear.

In this study an approach to land classification has been made on the basis of productivity rating index (i.e. Storie's index). These productivity indices have been calculated after studying all the physico-chemical characteristics of the soil (i.e. land).

The area under study extends over 500 sq. kms. which includes administrative units of Rampurhat P. S. and parts of Naihati and Mayureswar P. S. of district Birbhum, West Bengal.

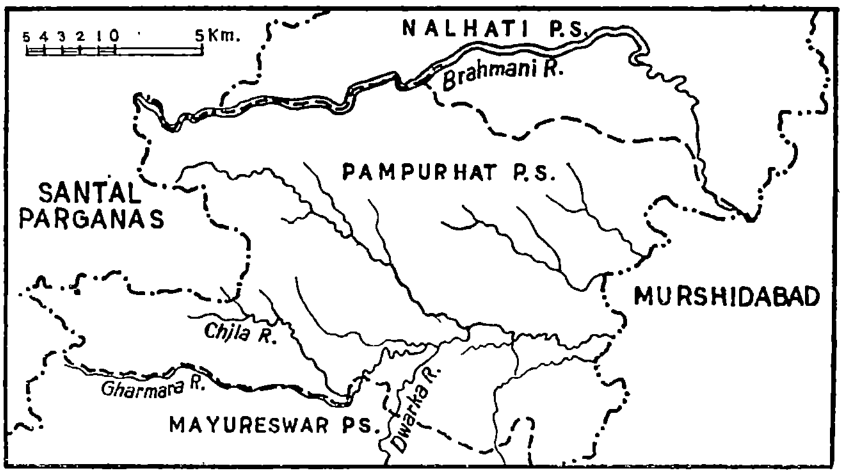
In any field of study classification is really a complicated practical job. Difficulties are found in delineating the limits for different groups and sub-groups. The question arises why should we attempt to delineate and classify different types of lands. The object of land classification is to help in classifying the possible uses to which the land can be profitably put.

In our study we will concentrate on agricultural land classification on the basis of concept of soil productivity rating, though "land classification is combination of classification of physical environment (soil) which can be described objectively, with a classification of the economic and social environment, which, by its nature can only be described subjectively (1946)."

If agricultural land planning be the definite goal, it can be simplified in most cases to the maintenance and enhancement of soil fertility by adopting a scientific landuse pattern that will best achieve that purpose. Albeiter (1940) is of opinion that "to summarise the situation in respect to productivity rating there appears to be no question but what their utility as a goal for a land classification is generally recognised".

It can be safely stated that a quantitative picture of soil fertility will be of more practical aid to the cultivators and for agricultural planning. In order to satisfy the increasing demand for a defined representation of soil fertility a number of systems have been devised for making quantitative estimates of productivity of soil types from various data.

Storie's system may be employed to illustrate this inductive method in rating soils for agriculture. In this system the ratings are calculated from percentage values awarded to certain soil characteristics. The values of eight factors (i e. chemical capacity, acidity or alkalinity, character of the profile, texture, slope, drainage, erosion, micro-relief), expressed as percentages, when multiplied together and subsequently the result expressed in percentage would express the necessary index for soil productivity after Storie (1933), i.e. $\frac{A}{100} \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100} \times \frac{G}{100} \times \frac{H}{100} \times 100.$



Map of the Study Area.
Fig. 1

It appears that if any one of the factors be low, the multiplied result will tend to be very low neglecting the other high values which seems to be a defect as pointed out by Jacks. A modification may be suggested as integrated rating index number which is equal to root of all multiplied factors, i e.

$$\sqrt[8]{A \times B \times C \times D \times E \times F \times G \times H}.$$

This would show inter action of all the factors rationally and in an uniform scale.

The region under study (Fig. 1) extends over 500 sq. kms which includes administrative units of Rampurhat Police Station, parts of Nalhati and Mayureswar Police Station of district Birbhum. It consists of nearly 220 villages and one urban unit and provides an excellent rural base for agriculture.

Sixty three soil samples were collected from a depth of 0- 22.5 cm (plough layer) from different spots of the region. They seemed to follow a definite geometrical pattern. Samples were collected after the harvesting of rice crop, while the field was nearly exhausted of applied fertilisers.

Now the productivity rating index values for these soil samples have been calculated as in the Appendix.

The Appendix indicates that Storie's index values range from 28 to 83 with wide variation in productivity rating. It must be stated that most of the soils have uniform characteristics in the field. Modified index calculations show the values varying within limited range of 83 to 98.

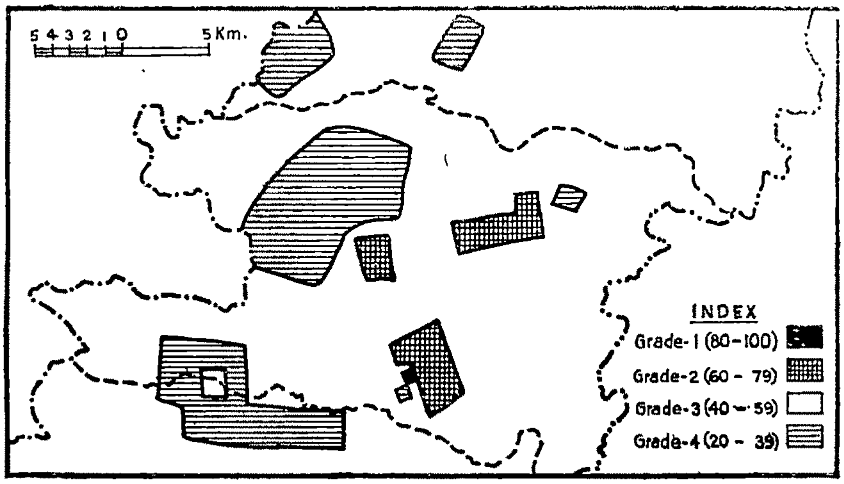
The Storie's index values are statistically correlated with the yield of *aman* paddy. It has been calculated that there is a strong positive correlation (0.8) between the Storie's index values and the crop yield. Storie's index values have direct influence on crop production, though it may be observed that chemical capacity index values are dominant over the index values of remaining factors. It will also be revealed that there exists a very strong positive correlation (0.9) between modified index values and crop yield (*aman* paddy).

Hence a land classification may be proposed on the basis of productivity rating index (Storie Fig. 2) as in Table-1.

From the Table-1 it is revealed that excellent and good lands which are suitable for different types of crops are geographically very limited. Most of the lands are of fair quality to support plant growth. Poor lands covering wide areas have narrow ranges in their agricultural possibilities. Some of them should be encouraged for afforestation so as to protect the surrounding cultivated lands. This may be implemented even by legislation, if necessary.

A proposition may also be made to classify lands on the basis of modified index values. (Fig. 3).

The Table-2 suggests that most of the lands support cultivation, though Grade I lands are quantitatively poor. Grade II lands cover the major areas and suited for all types of crop. Grade III lands also have extensive areas, but they should be put under proper management. Of the Grade III lands a portion should be given to forestry for effective



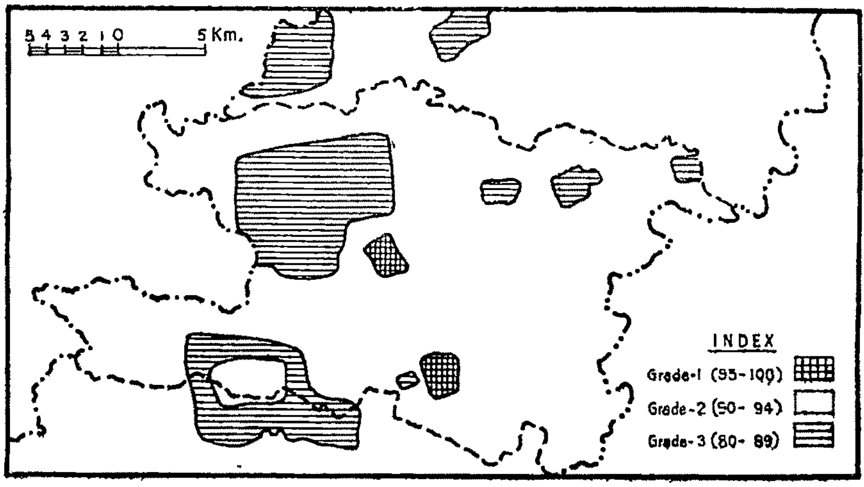
Land Classification—After Storie's Index values.
Fig. 2

conservation of soils in the lateritic tract to the west.

A geographical pattern emerges out when the land classification maps are examined that most of the poor lands lie on the older alluvium terrace and lateritic tract to the west of the Eastern Railway line, whereas the eastern newer alluvium country forms favourable cultivated lands.

TABLE—1

Group	Index limit	Soil sample no.	REMARKS
Grade I excellent	80- 100	54	Very good soil, with all favourable aspects of slope, drainage, relief, soil texture, chemical capacity etc. and needs very little management.
Grade II good	60- 79	1, 2. 3, 23, 29, 31, 32, 52, 55, 56	Good soil with all favourable aspects of slope, drainage, relief, soil texture, chemical capacity etc and needs fair management.
Grade III fair	40- 59	4, 5, 6, 8, 17, 18, 19, 20, 21, 22, 25, 26, 28, 30, 33, 34, 36, 38, 40, 41, 42, 45, 46, 47, 51, 57, 58, 59, 60, 61, 62, 63	Moderate soil with a few limitation in the aspects, i.e. slope, drainage, relief, chemical capacity, texture etc. and needs good management,
Grade IV poor	20- 39	7, 9, 10, 11, 12, 13, 14, 15, 16, 24, 27, 35, 37. 39, 43, 44. 48, 49, 50, 53	Moderate soils with more limitation in aspects, i e. slope, drainage, relief, chemical capacity, texture etc. and needs very good management.



Land Classification—After Modification of Storie's Index Values.
Fig. 3

TABLE—2

Group	Index limit	Soil sample no.	REMARKS
Grade-I More favourable to cultivation	95-100	1, 2, 3, 52, 54	Very good land with no limitation and needs a little management.
Grade-II Favourable to cultivation	90-94	4, 5, 6, 18, 20, 21, 22, 23, 25, 26, 28, 29, 31, 32, 33, 34, 36, 38, 40, 41, 45, 46, 47, 51, 55, 56, 57, 58, 59, 60, 61, 62, 63.	Good land with no limitation and needs good management.
Grade-III Less favourable to cultivation	80-89	7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 24, 27, 30, 35, 37, 39, 42, 43, 44, 48, 49, 50, 53	Medium land with one or two limitations and needs very good management.

APPENDIX

Sample No.	Chemical capacity	Acidity or Alkalinity	Character of the profile	Texture	Slope	Drainage	Erosion	Micro-relief	Storie's index	Modified index
1	2	3	4	5	6	7	8	9	10	11
1	85	98	100	85	98	100	100	100	69	96
2	93	98	100	70	100	100	100	100	64	95
3	80	98	100	85	98	100	100	100	65	95
4	71	98	100	85	98	100	100	100	58	93
5	57	98	100	85	98	100	100	100	47	91
6	45	98	100	100	100	100	100	100	44	90
7	51	98	95	85	90	90	92	95	29	85
8	54	98	98	95	100	90	95	100	42	90
9	50	95	95	85	90	90	92	95	28	85
10	35	100	100	85	100	100	100	100	30	86

(*Continued*)

1	2	3	4	5	6	7	8	9	10	11
11	44	98	100	70	98	100	100	100	30	86
12	45	98	100	85	100	100	100	100	37	88
13	45	98	100	85	100	100	100	100	37	88
14	37	98	100	65	100	100	100	100	24	83
15	45	98	100	85	100	100	100	100	37	88
16	51	96	100	65	98	100	100	100	31	86
17	52	96	100	85	98	100	95	100	40	89
18	51	98	100	100	98	100	95	100	47	91
19	64	98	100	85	98	100	100	100	52	92
20	60	98	100	100	100	100	100	100	59	94
21	52	98	100	100	100	100	95	100	48	91
22	66	98	100	70	100	100	100	100	45	91
23	75	98	100	85	100	100	100	100	62	94
24	37	98	100	100	100	100	100	100	36	88
25	71	96	100	85	100	100	100	100	58	93
26	61	98	100	85	100	100	100	100	51	92
27	43	98	100	70	98	100	100	100	29	86
28	53	98	100	85	100	100	100	100	44	90
29	65	98	100	100	100	100	95	100	61	94
30	53	98	100	85	100	100	100	100	44	86
31	72	98	100	85	100	100	100	100	60	94
32	63	98	100	100	100	100	100	100	62	94
33	56	98	98	100	98	90	92	95	41	90
34	56	98	100	95	100	100	100	100	52	92
35	42	98	100	95	98	100	100	100	38	89

(*Continued*)

1	2	3	4	5	6	7	8	9	10	11
36	63	98	100	95	98	100	95	100	55	93
37	40	98	98	95	95	100	92	95	30	86
38	71	98	100	70	98	100	95	100	45	91
39	48	98	98	95	95	100	95	95	38	88
40	63	98	100	95	98	100	95	100	55	93
41	62	98	100	85	100	100	100	100	52	92
42	70	98	100	60	100	100	100	100	41	89
43	52	98	100	70	100	100	100	100	36	88
44	56	98	100	65	100	100	100	100	36	88
45	56	98	100	85	100	100	100	100	47	91
46	59	98	100	85	100	100	100	100	49	91
47	55	100	100	85	100	100	100	100	47	91
48	45	98	100	70	98	100	100	100	30	86
49	64	98	98	85	95	90	92	95	39	89
50	63	98	98	70	95	95	95	95	34	87
51	72	98	100	70	100	90	100	100	44	90
52	68	98	100	100	100	100	100	100	67	95
53	62	98	100	70	100	90	100	100	38	87
54	100	98	100	85	100	100	100	100	83	98
55	65	98	100	100	100	100	100	100	64	94
56	72	98	100	85	100	100	100	100	60	94
57	50	100	100	85	98	100	100	100	42	90
58	69	98	100	85	100	100	100	100	57	93
59	61	98	100	85	98	100	100	100	50	92
60	58	98	100	85	98	100	100	100	47	91

(*Continued*)

1	2	3	4	5	6	7	8	9	10	11
61	66	98	100	85	98	100	100	100	54	93
62	82	98	100	70	100	100	100	100	56	93
63	67	98	100	85	98	100	100	100	55	93

REFERENCES

Albeiter, J. K. (1940) : *Productivity rating of soil types* ; Proceedings of the First National Conference of Land Classification ; Columbia, Missourie.

Jacks, G. V. (1946) : *Land classification for land-use plannnig* : Imperial Bureau of Soil Science, Technical Communication no. 43.

— (1954) : *Soils* : Thomas Nelson & Co., London.

Storie, R. E. (1933) : *An index for rating the agricultural value of Soils* : Californian Agricultural Experimental Station Bulletin, California.

— (1950) : *Transactions* : Fourth International Congress of Soil Science.

URBAN INDUSTRIAL PATTERN OF THE BHAGIRATHI-HOOGHLY BASIN

C. R, PATHAK AND R. N. CHATTOPADHYAY

Abstract

The Bhagirathi-Hooghly Basin is a distinct region with traditional industries, concentrated urban centres, a well developed transport network amidst vast tracts of fertile agricultural land. Geographically the region includes the Ganga-Brahmaputra Delta and the old alluvial flood plains of the Ganga tributaries inclusive of the Damodar. Rarely in India one finds such a combination of fertile soils and productive climate resulting in high agricultural yields particularly of rice and jute. Jute, chemical, heavy and light engineering, consumer goods and all types of ancillary industries have concentrated here during the course of years due to the availability of factors advantageous to industrial localization. Emerging industrial towns like Durgapur and Siliguri, new port of Haldia and the construction of Farakka Barrage will have great impact on the development of the region. There already exists a well linked inter-regional and intra-regional transport network facilitating flow of goods. Here lies the Port of Calcutta which handles almost the entire export-import enterprise of Eastern and Central India.

These functions have resulted in the growth of urbanization of immense magnitude creating a huge conurbation at the core with a maldistributed urban system in the rest of the region. A continuous influx of refugees after the political partition of the country has greatly enhanced the problems of urban congestion, housing shortage, unemployment, food scarcity and heavy pressure on agricultural land in the region.

This paper aims at analysing the planning problems of this region against the background of its urban industrial growth, linkage development and functions of flow and achieving rational policies for a programme of urbanization and urban industrial builds.

The role of the Bhagirathi-Hooghly river has been very important in shaping the urban-industrial pattern in the whole of southern West Bengal in general and along both the banks of the river in particular. The river acted as a chief artery for riverborne traffic even before the advent of railways in India and since earlier part of the 19th century or from the very beginning of industrial era in Bengal. The location of jute textile industry and its flourish along the banks of this right hand distributory of the river Ganga are too well known to need further introduction. The jute textile has been the very basic industry along the river banks from the very beginning until today when there has been much diversification in the industrial structure along its banks. During the twentieth century while industries have spread in many localities of southern West Bengal and Chota Nagpur Plateau of southern Bihar, more specifically along the Damodar river, a tributary to the Bhagirathi-Hooghly, the industrial concentration has been much intensified along the Bhagirathi-Hooghly banks, especially close to the Calcutta Metropolis.

The urbanisation pattern that has developed in the southern West Bengal, more particularly along the Bhagirathi-Hooghly banks, has its origin with the siting of industrial towns. Although there existed a number of trading centres (villages) in pre-railway era along the Bhagirathi-Hooghly banks and the very metropolis of Calcutta had been founded on trading and defence ground during the period of East India Company rule in India, majority of the urban centres along the banks were of industrial origin and their growth and development were largely conditioned by the industrial expansion during last half a century.

The Bhagirathi-Hooghly river has acted as the spinal chord of development of this linear urban industrial belt. Although the two branches of Eastern Railway paralleling the river in the north, and South-Eastern and Calcutta-suburban railways in the south of Calcutta, and the historic Grand Trunk Road complets the transport net work of this industrial belt ; until the independence of India, railways and roads had not provided proper linkages to the industrial centres.

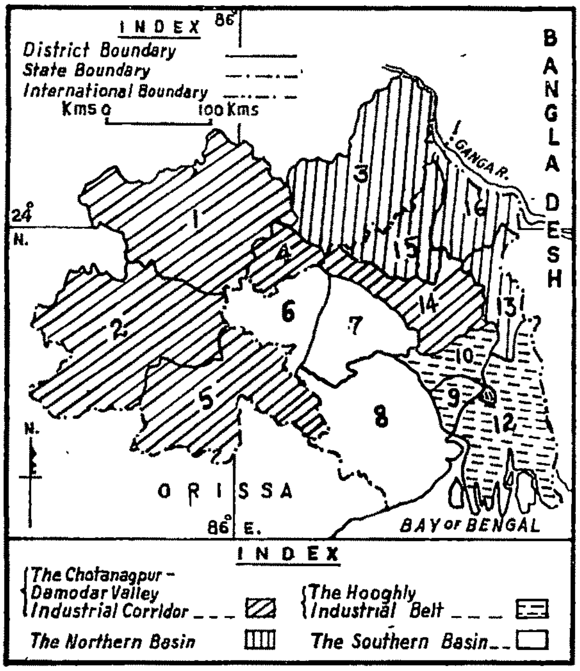
The main purpose of this paper is to analyse the urban-industrial growth pattern in the Bhagirathi-Hooghly Basin as influenced by its river system, to understand the present-day problems of urban-industrial development in the Basin and to suggest some guidelines for future urban-industrial growth in the Basin and more particularly along the Bhagirathi-Hooghly bank where urban-industrial agglomeration has already caused acute planning problems.

ECONOMIC REGION

Since the root of the urban-industrial planning problems of the industrial belt along the Bhagirathi-Hooghly banks lies in the resource structure of its hinterland, in the process of their exploitation and utilization, in their flow pattern and the movement of products for final consumption in its hinterland rather than in the industrial belt itself, its analysis must be based on three levels :

(a) the three State regional framework which comprises the broad hinterland consisting of Orissa, Bihar and West Bengal, (b) the Bhagirathi-Hooghly Basin as delineated for this study and (c) the four sub-regions as identified in the Basin region on development indices.

The three-State region comprising the states of Bihar, Orissa and West Bengal forms the most important macro-economic region in India within which the Bhagirathi-Hooghly Basin has been the economic hub. Although the Basin could largely be delineated by its domain of subaerial flows of river systems, economic viability of the Basin region should also be considered for integrated regional development. When a number of development and other indices are used, the Bhagirathi-Hooghly Basin is found to include the districts of its catchment area plus parts of Chota Nagpur Plateau. (Pathak *et al*, 1970)



1. Hazaribagh; 2. Ranchi; 3. Santal Parganas; 4. Dhanbad; 5. Singhbhum; 6. Purulia; 7. Bankura; 8. Midnapur; 9. Howrah; 10. Hooghly; 11. Calcutta; 12. 24-Parganas; 13. Nadia; 14. Burdwan; 15. Birbhum; 16. Murshidabad.

Fig. 1

The Bhagirathi-Hooghly Basin

The Bhagirathi-Hooghly Basin (Fig.-1) covers an area of about 51,598.2 square miles comprising 16 districts of Santal Parganas, Dhanbad, Hazaribagh, Ranchi and Singhbhum of southern Bihar and Murshidabad, Nadia, 24-Parganas, Calcutta, Birbhum, Burdwan, Purulia, Bankura, Midnapur, Hooghly and Howrah of southern West Bengal. The Basin starts on the north in the district of Murshidabad near Farakka where the Bhagirathi-Hooghly branches out from the river Ganga and extends south-westward covering the drainage basins of a number of tributaries like the Damodar, the Mor, the Ajay, the Kangsabati, the Rupnarayan and the Rasulpur and also a part of upper Subarnarekha basin covering Ranchi and Singhbhum districts.

The Basin has been delineated on the basis of development indices in the Three State Regional Framework and the same indices further divide the Basin into four distinct subregions. (Pathak *et al*, 1970).

a. The mineral-rich Chota Nagpur Plateau inclusive of the Damodar

Valley of which a string of urban-industrial centres forming polynuclear city region is the core and henceforth is expressed as *Chota Nagpur-Damodar Valley industrial corridor*. This subregion covers the districts of Burdwan of West Bengal and Dhanbad, Hazaribagh, Ranchi and Singhbhum of Bihar ;

b. *The Hooghly Industrial Belt* of which the Calcutta Metropolitian District (CMD) is the urban-industrial core. This subregion covers the most urbanized and industrialized districts of Hooghly, Howrah, 24-Parganas and Calcutta of West Bengal ;

c. *The Northern Basin* comprising the districts of Santal Parganas of Bihar and Murshidabad, Birbhum and Nadia of West Bengal, is mainly an agricultural region ;

d. *The Southern Basin* covers the districts of Purulia, Bankura and Midnapur of West Bengal and is a backward agricultural region.

The Bhagirathi-Hooghly Basin had a population of about 39.7 million in 1961 of which 30.8 million were rural and 8.9 million urban against 28.4 million in 1951 of which 21.7 million rural and 6.7 million urban. The Basin is expected to accommodate about 67 million people in 1981 of which more than a quarter is likely to concentrate in urban-centres (Table 1).

INDUSTRIALIZATION AND INDUSTRIAL PATTERN

The Bhagirathi-Hooghly Basin had become one of the world's largest industrial region employing about 2.3 million workers in secondary industries in 1961 of which about 8 lakhs or one third have been employed in registered factories. The employment in secondary industries had increased from 0.6 million in 1951 to 2.3 million in 1961 or 290 per cent increase.

The Basin had lead in industrial development in Indian history of industrialization since the middle of the 19th century when industries were first sited on the banks of the Hooghly river. The jute manufacturing has been the foremost industry in the Basin as has been cotton textile in Bombay-Ahmedabad region of western India. Jute maintained its unrivalled position since its inception until the World War-I when along with jute, a number of industries like cotton textile, food processing and mineral-based metallurgical and engineering industries were introduced to the Hooghly-side industrial scene. Iron and steel, and other basic metal industries sprang up along the Damodar Valley (Burnpur-Kulti) and in the Chota Nagpur Plateau (Jamshedpur) by the beginning of this century, when the industrial development of the Basin was found to take place in two locations : (a) iron and steel and other metallic industries in Chota Nagpur-Damodar Valley corridor facilitated by the availability of good quality iron ore in the Plateau, coal in the Damodar Valley, industrial water from the tributaries of the Hooghly and the Subarnarekha, cheap labour of southern Bihar, good railway linkage with the Calcutta-Hooghly industrial belt and many other factors and the other—(b) the jute textile with excessive concentration along the Hooghly bank north and south of Calcutta. This

TABLE—1

Existing and Projected Population in 1951, 1961 and 1981 (in lakhs)

No.	Area (sq. miles)	1951				1961				1981**			
		Total	Rural	Urban	Percentage of urban	Total	Rural	Urban	Percentage of urban	Total	Rural	Urban	Percentage of urban
1.	Chota Nagpur Plateau Damodar Valley Corridor.	82.02	72.53	9.49	11 57	108.25	95.30	12.95	11.96	183.60	148. 0	40.10	27.00
2.	Hooghly Industrial Belt	77.44	29.12	48.32	62.40	134.18	70.99	63.29	47.17	240 91	125.91	115.00	47,70
	(2a) CMD*	(—)	(—)	(—)	(—)	(67.21)	(7.29)	(59 92)	(89.15)	(109.65)	—	(109.65)	100.00
3.	Southern Basin.	62.25	57.99	4.26	6.84	73.66	68.17	5.49	7.45	103.20	88 50	14.70	14 24
4.	Northern Basin.	62.49	57.42	5.07	8.11	81.24	73.71	7.53	9.27	137.40	126.30	11.10	8 08
	The Bhagirathi-Hooghly Basin	284.20	217.06	67.14	23.62	397.33	308.07	89.26	22.46	670.11	489 00	180.90	27.00

* CMPO

** 1951-61 rate of growth is used for projections (1981).

industrial development was facilitated by the availability of raw jute from East Bengal (now Bangladesh) through the waterways of the Bhagirathi-Hooghly and other distributaries of the Ganga river system, good quality coal from Raniganj coal field of the Damodar Valley, cheap industrial labour from southern Bihar, nearness to Calcutta market and port for ultimate despatch to foreign market through water transport along the Hooghly and the availability of industrial raw material from the Chota Nagpur-Damodar Valley corridor through railway transport.

The industrial structure of the Hooghly belt has now become most diversified with the inclusion of cotton textile, food processing, metal and engineering, aluminium and a number of chemical industries. The modern industries sprung up in the Hooghly belt after the partition of India in 1947, since when the jute textile suffered a great setback due to the non-availability of raw jute supply from East Pakistan. There had been many other socio-political and economic causes for further decline in jute industry along the Hooghly bank during the successive development plan periods. However, this belt continued to witness a rapid pace of industrial growth during the development plan periods. Particularly a number of market-oriented industries grew although jute continued to decline.

During the development plan period, especially during the Second Plan, the Chota Nagpur-Damodar Valley corridor emerged as a very fast growing industrial area with iron and steel and other basic metal industries, coal-based and coal-oriented chemical and other industries, heavy machineries and machine tools, mining machineries, glass and ceramics and even many consumer goods industries. Power production from the D. V. C. system has been an important industry and a basic input for other industries. Many of the existing private sector industries like—IISCO at Asansol and TISCO at Jamshedpur, expanded their capacity and production. A number of public sector industries have also developed in the industrial corridor like the industrial complex at Durgapur, iron and steel at Bokaro, heavy machine tools in Ranchi, explosive and refractories near Hazaribagh and fertilizer at Sindri; a large number of medium and small scale industries under private sector have also developed in this corridor during the 1960's.

Thus, while the Hooghly belt experienced proficiency is engineering and chemical industries inspite of decline in jute, the western Basin (Damodar Valley Corridor) had tremendous industrial growth during the plan period. The other two subregions, namely the northern and southern Basins started at a very low level. In 1951 they had about 3.1 per cent and 20 per cent of (secondary) industrial workers of the Basin respectively. During the decade 1951-61, the northern Basin had shown tremendous increase in industrial employment especially since the river valley projects were undertaken but still shared less than 10 per cent of the Basin's total industrial employment. The southern Basin although had an increase in industrial employment of about 190 per cent, its percentage share of employment had gone down from 20 per cent in 1951 to 15 per cent in 1961 (Table-2).

From Table-2 it is clear that the Hooghly belt has the lion's share of the regional industrial employment (54 per cent) followed by the Industrial Corridor of western Basin (21.1 per cent). When employment in manufacturing alone is considered, Hooghly belt commands 65 per cent or 11 lakh workers out of 17.5 lakh workers of the entire Basin. The Basin had an industrial income of Rs. 3054.8 lakhs in 1961-62. The Hooghly belt alone had share of about 68.5 per cent (Rs. 2089.0 lakh) of the Basin's income followed by 17.2 per cent (Rs. 524.7 lakhs) of the Chota Nagpur-Damodar Valley Corridor. Northern and southern Basins had 8.7 per cent (Rs. 266.4 lakhs) and 5.6 per cent (Rs. 174.7 lakhs) respectively.

The industrial structure and growth pattern in the Bhagirathi-Hooghly Basin will be clear from comparative growth rate analysis of industrial groups.

The Basic metal and engineering industries had very high growth rate in the Hooghly belt and also in the Chota Nagpur-Damodar Valley Corridor while there had been a significant decline in jute industry in the Hooghly belt.

URBANIZATION AND URBAN PATTERN

Although a number of urban centres pre-existed the modern industrial era in the Bhagirathi-Hooghly Basin, the level of urbanization had always been very low. The nineteenth century urban centres were either the seats of the then feudal lords (Zamindars/Rajas/Maharajas

TABLE—2

Secondary Sector Employment and its Growth

Region :	Secondary workers (in lakhs)				Percentage increase of secondary workers
	1951		1961		1951-61
	No.	Percentage of total Basin.	No.	Percentage of total Basin	
1. Chota Nagpur D.V. Corridor	2.7	43.9	4.94	21.3	85.0
2. Hooghly Industrial Belt	2.20	32.9	12.70	54.2	535.0
3. Southern Basin	1.24	20.2	3.59	15.2	189.5
4. Northern Basin	0.19	3.0	2.17	9.3	1042.1
Bhagirathi-Hooghly Basin	6.33	100.0	23.40	100.0	290.1

Source : Census of India—1951 & 1961.

or Nawabs) or trading centres or places of pilgrimage and cottage industries. Only the capital cities of some zamindaries prospered as administrative-cum-business centres. The modern cities were founded during the British rule mainly towards the middle of the 19th century along the Hooghly banks.

By the turn of this century a number of industrial cities emerged in the Basin like Howrah, Jamshedpur, Asansol etc. Many more had been added which prospered during the development plan period like Sindri, Chittaranjan, Durgapur, Bokaro as chosen centres for selected industries.

At the beginning of this century, the Bhagirathi-Hooghly Basin had only 2 million urban people which increased to 5 million in 1941, 6.7 million in 1951 and 8.9 million in 1961 or had an increase of + 329 per cent during 1901-61, + 75 per cent in 1941-61 and + 33 per cent in 1951-61. The Basin, thus, reached an urbanisation level of 22.1 per cent in 1961. The overwhelming majority of rural population and high rate of natural increase in total population kept the urbanisation level low.

Within the Basin there has been a great variation in urban population growth among the subregions the Chota Nagpur-Damodar Valley Industrial Corridor experienced a percentage increase of more than 600, Hooghly belt and the northern Basin experienced 300 per cent, and the southern Basin only 195 per cent during 1901-61. The Industrial Corridor of course, started with a very low urban base at the beginning of this century, like the northern and southern Basins, while the Hooghly industrial belt with the city of Calcutta started with about 16 lakhs of urban population or 74 per cent of Basin's total urban population in 1901. Even in 1961, this belt accounted for about 71 per cent of total urban population of the Basin. However, the Industrial Corridor shared about 14 per cent of Basin's urban population in 1961 (Table 3.)

The Hooghly industrial belt has been most urbanised attaining an urbanisation level of 47 per cent in 1961 while those of the Chota Nagpur-Damodar Valley-Industrial Corridor are 12 per cent, the northern Basin 9 per cent and southern Basin 7 per cent only. Surprisingly, the urbanisation level in the Basin had shown a decline from 23 per cent in 1951 to 22 per cent in 1961 although there had been a significant increase in urban population figure. This decline is more prominent in Hooghly belt where the level declined from 62 per cent in 1961 to 47 per cent in 1961. This was partly due to the census definitional changes of urban places from 1951 to 1961, but mainly because of the fact that population increase has been more in the rural sector during this decade both due to high natural increase and migration to mining areas of the Damodar Valley and the rural areas of the Hooghly banks. The latter one has been contributed by the refugee influx from East Pakistan (Bangla Desh). While the urban population in the Basin grew by 33 per cent during 1951-61 decade, the rural population increases by 88 per cent ; in the Hooghly belt the corresponding percentage increases for the same period were 31 and 145 respectively. This low rate of urbanisation in the Basin and more particularly in the Hooghly industrial belt, is a very significant phenomenon.

TABLE—3

Urban Population Pattern : 1901-61 (in lakhs)

Regions :	1901 No.	1941 No.	1951 No.	1961 No.	1961 Percentage of total	Percentage Growth 1901-61	Percentage Growth 1941-61	Percentage Growth 1951-61
1. Chota Nagpur Damodar Valley Corridor	1.78	6.40	9.49	12 96	14 41	+ 627 5	+ 102.4	+ 36.5
2. Hooghly Industrial Belt	15.80	37.30	48.32	63.29	71.01	+ 300.6	+ 69.6	+ 31.0
3. Southern Basin	1.86	3 40	4 26	5.49	6.14	+ 195.2	+ 61.5	+ 28.4
4. Northern Basin	1.88	3.62	5 07	7.53	8 44	+ 300.5	+ 108.0	+ 48.5
The Bhagirathi-Hooghly Basin	21.32	50.72	67.14	89.26	100	+ 328.6	+ 75.0	+ 32.9

Source : Census of India, 1901, 1941, 1951 & 1961.

This rate of urban growth of the fifties may adversely affect the urbanisation pattern of the Hooghly belt in future also.

It is expected that in 1981, the Basin would have about 67 million people or an increase of about 70 per cent over 1961 ; while urban population load would be about 18.1 million or more than 100 per cent increase over 1961. Since the Hooghly-side industrial belt has already shown decline in urban growth rate, only by providing a bigger push to urban growth with revitalisation of industrial opportunity, this belt can support at best 11.5 million urban population in 1981. The CMD is likely to urbanise 100 per cent and there will be about 11 million total or urban population.[1] The rest half a million urban population of the Hooghly belt has to be distributed outside the CMD area. The northern Basin would accommodate about 4 lakhs more urban population in 1981 over and above its present share of 7.5 lakhs in 1961. However, its urbanisation level would not rise beyond 8 per cent. The southern Basin has some prospect with the creation of Haldia towdship in Midnapur and Santaldih-Ramkanali complex in Purulia district and is expected to gain more than 8 lakhs urban people during 1961-81 raising its urbanisation level from 7.4 per cent in 1961 to 14.2 per cent in 1981.

The most prospective region in the field of both industrialisation and urbanisation is the Chota Nagpur-Damodar Valley Industrial Corridor where urbanisation level can be raised from 12 per cent in 1961 to 27.0 per cent in 1981. The urban population load is expected to increase by 125 per cent during 1961-81.

There were about 217 towns and cities in 1961 in the Bhagirathi-Hooghly Basin out of which 14 are cities each with over a lakh of population including the metropolis of Calcutta ; 19 big towns with population between 50,000 and one lakh ; 60 medium size towns and 124 small towns. The cities accommodated about 7.9 million out of Basin's 8.9 million urban population in 1961, or 89 per cent out of which Calcutta alone had 2.9 million or 33 per cent of total urban population. Once again out of 14 cities, 9 are located within the CMD. We have already noted that the Hooghly belt accounted for about 71 per cent of Basin's total urban population in 1961 and is expected to share 63.5 per cent in 1981. This excessive urban concentration in the Hooghly side industrial belt has resulted in lop-sided urban development leaving a very insignificant share of urban load for the rest of the Basin.

The class II and III towns together support only a quarter of total urban population load of the Basin, of which majority are again concentrated in the Hooghly-side industrial belt. The remaining three classes of towns share only 18.6 per cent of urban population load of the Basin.

The above pattern of urban population distribution has set a pattern of urban structure i.e. urban population growth has been concentrated mainly in the big cities which are also major industrial centres and located within the industrial belts. Since this pattern is likely to continue during 1961-81, most of urban population increase will be in these major towns and cities of the Basin. This unmistakable urban growth trend would again bypass the smaller urban centres in the southern and northern Basins.

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1. Basic Development Plan, CMD—1966-86
—CMPO—p. 69.

Even in the latter ones, growth is expected only in major centres.

Future urban growth in the Bhagirathi-Hooghly Basin would be definitely determined by its industrialisation pattern and public policy in the immediate future. The extent of urban growth due to industrialisation or *vice-versa* could be measured by analysing the present day relationship between urban pattern and industrial pattern in the Basin. This relationship has been established here by the correlation analysis between district-wise indices of industrial concentration and indices of urbanisation. The above indices had a positive correlation in 1961 i.e. + 0.74 and this was very significant. Again, $r^2 \sim 0.50$ signifies that more than half of the variations in urbanisation performances of the districts is explained by the performances of concentration of industrial activities.

The regression analysis of the above two indices further establishes the fact that urbanisation has been consequential to industrialisation in the Basin (Pathak, 1968). The equation is given by

$$I_u = 0\,266 + 0.736\ I_i$$

where I_u = Index of urbanisation

and I_i = Index of industrial concentration.

Most of the districts come within the acceptance region except Calcutta which is over-urbanised compared to its level of industrialisation and Howrah and Santal Parganas which are ahead in industrialisation and where urbanisation is lagging behind (Fig. 2). The above relationship is expected to guide the future urban-industrial pattern in the Basin. Gain in industrial employment for a particular region would mean increasing urbanisation and loss in share of industrial employment might result in deceleration in urbanisation. This is very evident in the Hooghly industrial belt where decline in industrial employment is expected, so also in its urbanisation rate. The only major reliever of both urban-industrial load of the Hooghly belt is the Chota Nagpur-Damodar Valley Corridor which is expected to share 26 per cent of total manufacturing industrial employment of 4 million of the Basin and about 22 per cet of 18.0 million urban population (Table-4.0) in 1981.

The analysis in Table-4 clearly demonstrates urban industrial dispersion in the Basin during 1961-81. An analysis of most recent urban-industrial trend (1961-70) would further substantiate the above findings. A recession has already set in the Hooghly side industrial belt both in urbanisation and industrialisation. We must be cautious about this trend and see that it must not affect adversely the growth of the Chota Nagpur-Damodar Valley Industrial Corridor—the most prospective and fastest growing urban-industrial belt of the Bhagirathi-Hooghly Basin.

Further Urban-Industrial Pattern

Within the Bhagirathi-Hooghly Basin region, the manufacturing industries have concentrated in a giant arc from the CMD on the south-east to steel magnets of Jamshedpur-Rourkela-Bhilai (last two are the extension of coal-steel belt of India) on the south-west swinging through the resource-based industries of

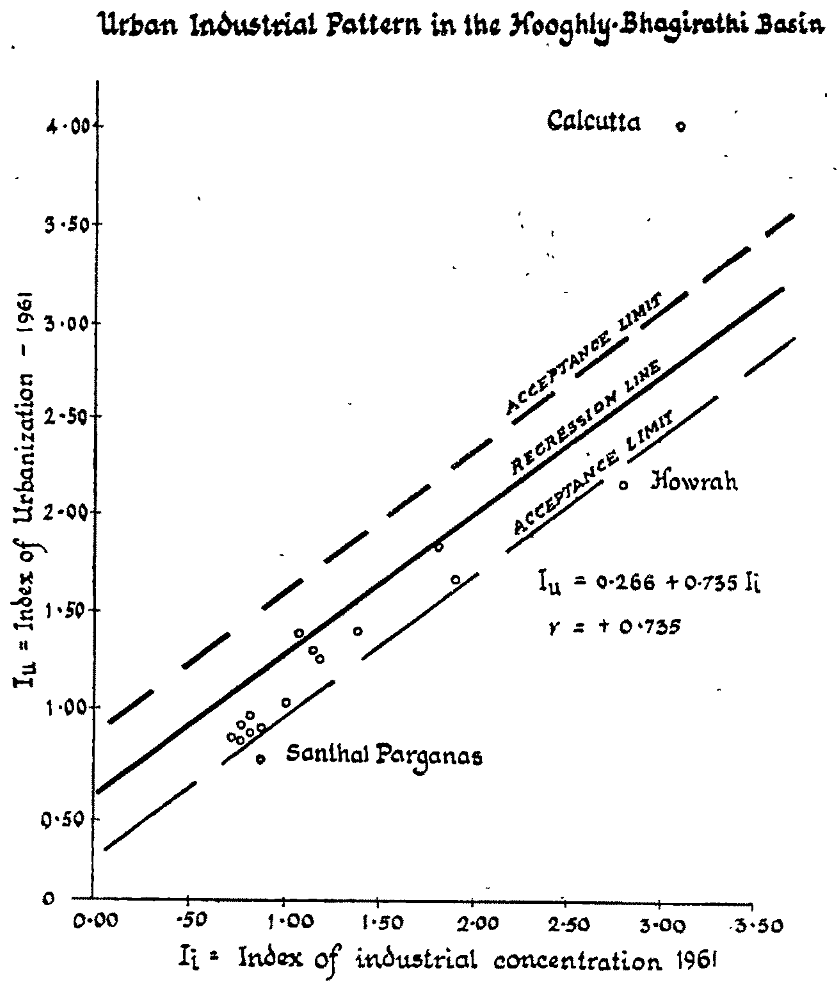


Fig. 2

TABLE-4

Industrial employment (in lakhs) in 1961-81

(only manufacturing)

Regions	1961		1981	
	Employed	Percentage	Employed	Percentage
1. Chota Nagpur D. V. Corridor	1.94	11.0	10.28	26.0
2. Hooghly belt	11.10	65.4	18.79	47.6
3. Southern Basin	1.98	11.3	7.50	18.9
4. Northern Basin	2.15	12.3	3.00	7.0
Basin	17.17	100.0	39.57	100.0

the Damodar Valley forming one of the world's largest industrial crescent.

This jute-coal-steel industrial belt has developed in the form of a railway string with industrial centres as knots with a tendency to create a linear urban system of interrelated industrial cities centred on the great port and market of Calcutta. An immense chain of rail, road and air connection radiating westward from the CMD binds these industrial centres to Calcutta and to one another. This industrial crescent has commanded a lion's share of national capital investment on urban industrial development and clearly this must continue to be the case over the decades to come both as a policy of decentralising urban-industrial load of the Bhagirathi-Hooghly-side industrial belt and as an objective to develop the resource rich but economically backward areas of central India.

Within this huge industrial complex which has now surpassed the territorial limit of the Bhagirathi-Hooghly Basin spatially, a great system of industrial cities is the dominant pattern of urbanisation with a vast concentration of cities along the Bhagirathi-Hooghly banks. Inspite of the recent urban-industrial growth in the Chota Nagpur Plateau and the Damodar Valley region, the urban load of the Hooghly bank has not diminished to any significant extent and the dominant migration pattern during 1951-61 has rather shown substantial urban population increase in the Hooghly-side urban centres. The excessive urban concentration in the CMD has rendered a remarkable imbalance in the urban pattern in the Three State Region of Bihar, Orissa and West Bengal. If this pattern continues even over the present decade only, urban population load on the Hooghly-side urban centres will be fantastic unless Damodar Valley and the Chota Nagpur Plateau area accommodate the major share of urban population growth.

The Bhagirathi Hooghly Basin is expected to urbanise at the same rate as in 1951-61 during the next two decades, which means that the Basin would have 18.1 million urban population in 1981 as against 8.9 million in 1961 or 103 per cent increase in 1981 over 1961.

What then would be the pattern of urban population distribution in 1981? The Hooghly belt is expected not to urbanise with very high rate. However, it is already highly urbanised (47 per cent) and it will maintain its present urban level through 1961-81. This means that the Hooghly belt would experience an increase of about 5 million urban population over its present load of 6 million during this period. Once again its urban population will remain concentrated in its CMD core. The CMD is already intensely urbanised and at best can accommodate about 11 million people in 1981 having attained a hundred per cent urbanisation level. This means a balance of about 7 million urban population to be accommodated in the rest of the Bhagirathi-Hooghly Basin.

The Chota Nagpur-Damodar Valley Corridor would have to urbanise at much faster rate than at least the Hooghly-side urban belt. The urban population growth rate of the Industrial Corridor must be as high as 200 per cent during 1961-81 to accommodate almost 4 million urban people in 1981.

The remaining 2.5 million urban population in 1981 would have to be distributed in southern and northern Basins. The northern Basin's economy revolves round agriculture and there is very little possibility of developing a very big industrial city. Only Krishnagar-Berhampur, Nabadwip, Santipur, Suri, Ranaghat and the proposed Farakka-Barharwa townships are the major market-cum-administrative centres, most of which are class II or III towns. These together with the small towns would have to accommodate about a million urban people in 1981.

The Kharagpur-Midnapur towngroup is the only major urban centre in the southern Basin. This industrial cum-administrative towngroup together with the proposed port-cum-industrial township of Haldia is expected to accommodate about a million people in 1981. The remaining half a million urban population of this region are to be distributed among Bankura, Purulia, Bishnupur, Tamluk and the proposed industrial township at Santaldih-Ramkanali and other small market-cum-administrative towns of the southern Basin.

So far most of the urban population load of the Basin has been concentrated in its major urban-industrial cities and this pattern is likely to continue through 1961-81. But without the development of small to medium size urban centres for sharing proportionate urban load, the result will be again an urban imbalance.

The trickle-down effect may not result fruitfully from the industrial magnets to the rural market-cum-service centres. The small urban centres must be considered as self-generating growth points where rural industries must find space for location. So far, the industrial magnets have not only overshadowed the small centres but also acted adversely in the location of small scale industries in these centres. This is a major strategy of urbanising the rural areas although they are in a much worse position to develop by locating in them small scale industries which may not be very economic at the start but this will definitely reduce the migration to either CMD or to the big cities but urbanise the rural area forming a sound base for over-all urbanisation.

The extension of better communication facilities in the rural areas, rural electrification and power supply, patronage for small scale industrial siting in them, facilities for industrial training, co-operative societies both for investment and marketing, tariff or other protection for rural products, supply of raw-materials at much cheaper rate, are the major steps in improving the socio-economic condition of rural areas.

Thus, the urbanisation plan for the entire Bhagirathi-Hooghly Basin will include the identification of growth centres of various order in the whole of 16 districts of southern Bihar and West Bengal. The urbanisation plan should be attempted on a regional level rather than on sub-regional level and on the ranking of different types of urban centres, which may be further differentiated through sub-regional programme levels for executing the urbanisation policies.

APPENDIX—1

Annual growth rate of employment by industry groups in per cent

Iudustry groups :	D. V. Region* (ex. Jamshedpur) 1958-65	West Bengal 1951-66	Hooghly side 1951-63
1. Basic metal	52.7	6.7	9.7
2. Engineering	420.2		4.8
3. Chemical & rubber	2.6	1.6	1.3
4. Jute	—	—1.1	—1.2
5. Cotton & other textiles	2.4	4.2	0.9
6. Food & Beverages, tobacco	2.9	0.8	2.4
All industries	12.2	4.8	1.6

* The Damodar Valley region here includes the districts of Hooghly, Howrah, Bankura & Purulia, but excludes Singhbhum district.

APPENDIX—2

Distribution of employment in Registered Factories (1961)

No.	Industry :	Chota Nagpur-D. Valley Corridor.		Hooghly Ind. Belt.		Southern Basin		Northern Basin		Bhagirathi-Hooghly Basin	
		No.	Percentage	No.	Percentage.	No.	Percentage.	No.	Percentage.	No.	Percentage.
1.	Basic Metal	86,273	69.55	37,635	30.34	—	—	120	0.11	124,028	15.60
2.	Other Engg.	35,353	17.72	151,049	75.72	12,676	6.35	420	0,21	199,498	25.10
3.	Chemical & rubber	36,355	41.76	48,308	55.48	1,476	1.70	922	1.06	87,061	10.95
4.	Jute Textile	—	—	201,510	100.00	—	—	—	—	201,510	25.35
5.	Cotton & others	2,360	3.98	54,486	91.90	115	0.19	2,331	3.93	59,292	7.46
6.	Food, Beverage & Tobacco	8,207	19.03	20,112	46.68	7,795	18.08	6,990	16.21	43,104	5.42
7.	Others	21,744	27.02	57,496	71.47	81	0.10	1,134	1.41	80,455	10.12
11	Industries :	190,292	23.94	570,596	71.78	22,143	2.78	11,917	1.50	794,948	100.00

Source : Chief Inspectors of Factories, West Bengal and Bihar.

APPENDIX—3

Existing and Projected Employment Pattern for the Bhagirathi-Hooghly Basin
(in lakhs of workers)

Regions	1951				1961				1981			
	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary
1. Chota Nagpur Damodar Valley Corridor.	17.79	14.76	2.67	2.29	42.89	28.24	4.94	9.71	76.40	43.61	15.38	17.41
2. Hooghly Industrial Belt.	9.30	3.80	2.00	3.50	43.30	16.20	12.70	14.40	78.28	30.17	22.28	25.83
3. Southern Basin.	23.05	19.53	1.24	2.25	26.75	19.87	3.59	3.29	41.27	25.88	10.80	4,59
4. Northern Basin	18,36	18.01	0.19	0 36	29.86	25.59	2.17	4.80	55.62	44.27	3.23	8.12
Basin as a whole.	70.50	56.10	6.00	8.40	142.80	88.90	23.40	32.20	251.57	143.93	51.69	55.95

Note : Mining workers have been included in secondary group.

APPENDIX—4

Major Urban and Industrial Centres and their estimated Population for 1981
(Population in lakhs)

Region :	Centre :	Urban Population 1961	Urban Population 1981
1. Chota Nagpur-Damodar Valley Corridor.	1. Durgapur T. G.	0.42	3.95
	2. Asansol-Burnpur T. G.	1.69	3.31
	3. Kulti-Barakar T. G.	0.34	0 87
	4. Chittaranjan	0.29	0.64
	5. Dhanbad-Jharia-Sindri T. G.	2.01	5.23
	6. Kumardhubi-Chirkunda-Maithon T. G.	0.43	0.66
	7. Bermo-Bokaro-Kargali-Jaridih Bazar T. G.	0.60	1.65
	8. Ranchi-Doranda T. G.	1.40	2.45
	9. Jamshedpur-Jugsalai T. G.	3.28	9.36
	10. Burdwan	1 08	2.43
	11. Other centres	1.41	9.75
	Total Region :	12.95	40.10

(*Continued*)

2. Hooghly Belt.	1.	CMD (Urban)	59 92	109.65
	2.	Other areas	3.37	5.35
		Total Region :	63.29	115.00
3. Southern Basin.	1.	Kharagpur-Midnapore T G.	2 08	7.00
	2.	Haldia	—	3.00
	3.	Purulia-Santaldih-Ramkanali T. G.	0,48	1.00
	4.	Bankura and Bishnupur	0.94	1.54
	5.	Other centres	1.99	2.16
		Total Region :	5 49	14.70
4. Northern Basin.	1.	Krishnagar-Santipur and Nabadwip	1 94	3.33
	2.	Ranaghat T. G.	0.55	1 63
	3.	Murshidabad-Berhampur	0.79	1.10
	4.	Farakka-Barharwa	—	1.00
	5.	Other centres	4.25	4.04
		Total Region :	7.53	11.10
Bhagirathi-Hooghly Basin			89.26	180.90

REFERENCES

CMPO (1965-66) : *Basic Development Plan for Calcutta Metropolitan District, 1966-86,* Calcutta Metropolitan Planning Organisation, Govt. of West Bengal, Calcutta.

Pathak, C.R. (1968) : *Urban-Industrial Pattern of the Damodar Valley Region,* Monograph.

Pathak, C.R., *et al* (1970) : *Identification of Planning Regions in the Three State Region,* Indian Journal of Regional Science, Vol. 2, No .1, Calcutta.

INDUSTRIAL CROSS-PROFILE OF THE NORTH-EAST CALCUTTA METROPOLITAN DISTRICT

SUNIL KUMAR SADHUKHAN

Abstract

Forming roughly the NE quadrant of the CMD, the NE-CMD offers a fascinating case-study of the degree of concentration of industries within the CMD.

The paper attempts to show that the growth rate of industries has not been uniform throughout the NE-CMD, an inseparable segment of the CMD. Differences in the rate of growth are attributable to various factors-facilities at the initial stage of development, nearness to Calcutta, strategic considerations ete.

Lack of ample data limits the study to a great extent but absence of reduction in the labour force through infra-structural rationalisation makes employment a major criterion for measuring growth, irrespective of direction.

Hitherto unimportant areas, away from the Hooghly side are getting entrepreneurs' preference due to disappearance of the initial advantages.

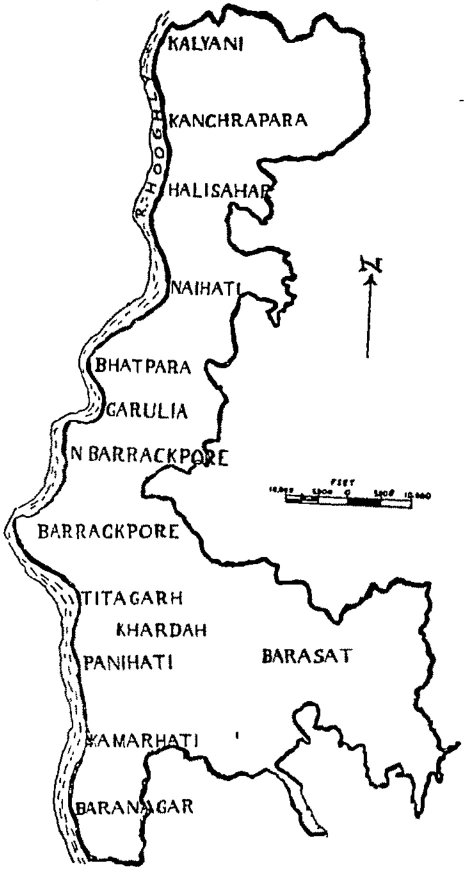
The declining influence of Calcutta northward seems to be inimical to the success of 'industrial estate' of Kalyani.

A direct relationship between population and industries growth is established in the urban-statistical graph which also shows the declining influence of Calcutta, an uneven growth of industries along the 26-mile stretch of the NE-CMD, running from Baranagar in the south to Kalyani in the north.

Just a glance at the industrial superstructure, dominated by jute, cotton, engineering, heavy chemicals and paper, reveals unequal growth in the production and in some cases negative growth.

Impediments and bottlenecks like limitations of space, under utilisation of installed capacity due to high cost of raw materials and the like, deterioration of the Calcutta port subsequent to the silting in the Hooghly, should not be allowed to prevail in the light of the abundant labour supply, scope of industrial diversification and the presence of a highly competitive market.

The North-East Calcutta Metropolitan District or the NE-CMD forms roughly the north-east quadrant of the Calcutta Metropolitan District. An attempt for a case-study and thereby a proper understanding of the industrial landscape justifies the selection of a segment of the greater Calcutta industrial area.



Study Area
Fig. 1

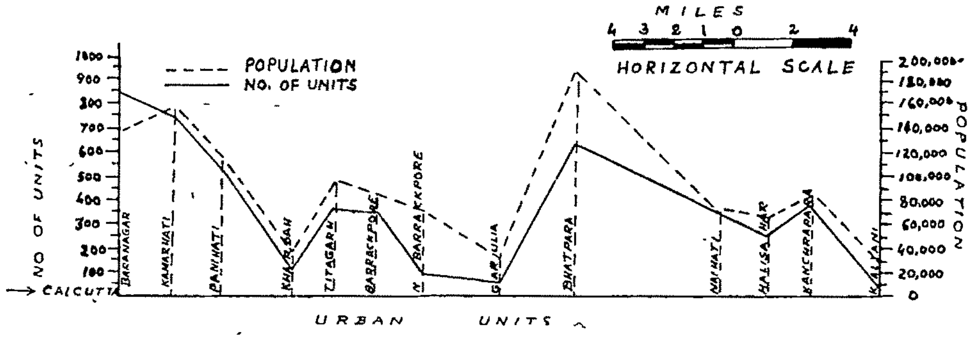
The paper with the help of some urban-statistical graphs will point out variations in the degree of concentration of industries within the NE-CMD and put forward reasons which are the findings of the author's own investigations.

CONCENTRATION OF INDUSTRIES

The line of section has been drawn along the 26-mile stretch of the NE-CMD from Baranagar in the south right upto Kalyani in the north. The section (Fig. 2) has been drawn not merely by joining a few points along the line of section but by taking different municipalities into consideration. For the sake of simplicity the name of Barasat has been omitted from the section. By measuring the distance between Baranagar and Barasat, it could have been placed in the section somewhere between Khardah and Titagarh. This deliberate omission testifies to an almost insignificant industrial growth even a little away from a certain line and in this light Barasat can be treated as a secondary industrial area. But the prospect of this area should not be underestimated in as much as its present backwardness is owing to the selection of the choicest places along the Hooghly by the entrepreneurs at the initial stage.

The whole section can be divided into a number of sectors. Again broadly, these sectors can be grouped into two categories—sectors of high concentration and sectors of low concentration. Baranagar-Kamarhati-Panihati, Titagarh-Barrackpore, Bhatpara and Naihati-Halisahar-Kanchrapara fall within the first category, while Khardah, North Barrackpore-Garulia, and Kalyani come under the second category.

A few points can, however, be put forward in explaining the shape of the profile. Some industries requiring greater space might have preferred peripheral location at the initial stage. Another advantage is provided by the Vivekananda Bridge over the Ganga which facilitates the movement of both raw materials into the area and finished products from the area. This area still has enough space for establishing new factories but the overcrowding of Calcutta obviates the attention of other entrepreneurs. The growth of the industries in Barrackpore is also historical.



Correlation between Population and Industrial Growth
Fig. 2

importance of the region as a residential area. The early attainment of municipal status by Baranagar and Kamarhati is indicative of the early concentration of population in this area. The population, municipal services, nearness to Calcutta and river-side location must have combined to put an impetus to the industrial growth of the region. The opening of railway and electrification multiplied the plentitude of advantages.

A second area of high concentration happens to be Titagarh-Bhatpara. The reasons behind the high concentration are easily explainable. Titagarh is noted for its early development in jute mill industry and subsequently paper industry. In fact, Titagarh has nine jute mills. For establishing the jute mills eastern bank of the Hooghly always got preference in choice because of the location of jute growing areas in that side before 1947. Titagarh due to its nearness to the Calcutta Port was given the utmost importance. The growth of this industry naturally drew the attention of other entrepreneurs. The growth of the industries in Barrackpore is also historical.

The high concentration in Bhatpara is attributable to several factors. In fact, the density of concentration in this area is by no means greater than those of other municipalities. The existence of this node is due to the greater municipal area. Apart from the presence of abovementioned advantages, Bhatpara has an early record of higher population. This area was well-reputed as a centre of Sanskrit education.

The Naihati-Halisahar-Kanchrapara node forms the last *high* of any magnitude at the northern end of the Calcutta Metropolitan District. Naihati and Kanchrapara have attained equal height, while Halisahar lying in between, happens to be a little lower. The shape can be easily explained if we focus our attention on a simple fact of the attainment of municipal status. Halisahar is a late comer as a municipal area. It clearly reveals that early industrial growth was far less compared to other municipal areas.

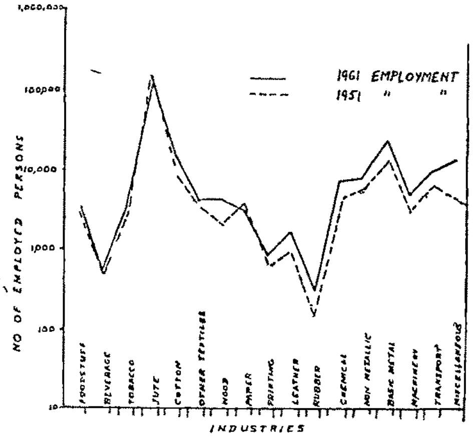
Bhatpara and Khardah are poles apart in the nature of industrial concentration in general, and the density of concentration in particular. While Bhatpara with its greater municipal area accommodates greater number of units, Khardah due to its nearness to Calcutta, invited the entrepreneurs to set up industries. Whereas Bhatpara owing to its early population concentration records an early industrial growth, Khardah comes to the picture much later. While greater space has been a determining factor for density to rise, it is the lack of space which has resulted in high density. But the most interesting fact is that space has outranked the nearness to Calcutta so far as the number of units is concerned.

The depression between North Barrackpore and Garulia is rather outstanding. This form is due to the presence of the cantonment area, giving less scope for any substantial industrial growth. Ichhapore, lying in between, happens to be a defence estate. So strategic consideration seems to have caused a little discontinuity in the industrial conurbation. Kalyani is only a newly-erected non-municipal township and happens to be one of the five industrial estates of the CMD, built in the line of *Industrial Estates* of U.K. and *Industrial Parks* of the U.S.A. Here sheds are alloted for manufacturing units to be set up but unfortunately in spite of all its facilities a large number of sheds remain unoccupied here. Considering its past performance even an optimist will decline to predict a bright prospect in near future. The proposed Kalyani-Bansberia bridge, if and when completed, and the completion of Farakka Barrage will stimulate the industrial activities of the area.

Although the entire profile consists of a number of *highs* and *lows* the declining influence of Calcutta northward hardly escapes one's notice.

EMPLOYMENT OPPORTUNITIES

After this study of micro-regional concentration of industries, a focus on the super-structure of industries will be useful. This part of the paper attempts to pinpoint the growth of the individual industries in either directions—negative or positive. The lack of data regarding capital investments and foreign exchange earnings of the individual industries limits the analysis to a great extent. The author, therefore, turns to the rise and fall of employment in each industry for measuring its growth irrespective of diversion. (Fig. 3).



Change in Industrial Employment
Fig. 3

The Jute Textile Industry

The Jute industry has suffered a decline although not of a great magnitude. A fall in the employment in the jute industry is apparent. During the study tour the author found quite a number of mills closed. The most outstanding reason was found to be higher prices of raw jute. The domestic reason coupled with the tough competition from the cheaper and finer Pakistani jute goods is making the profit margin narrower and narrower. Operating with old and obsolete machines and producing traditional goods the Indian exporters cannot afford to get the buyers' preference. So survival lies in the reduction of jute prices, rationalisation of infrastructure, and invention of newer items through research and experiments.

The Cotton Textile Industry

Unlike the Jute Industry, the Cotton Textile Industry plays an insignificant role among the textile industries of the NE-CMD. The NE-CMD shares about 21.3 per cent of the total employment in cotton textile industry in West Bengal. Of the total of 650,000 cotton textile workers in India, the NE-CMD employs nearly 25,000.

A close analysis of the locational factors reveals that the NE-CMD has ample scope for expansion of cotton textile industry. The only disadvantage the region suffers from, is the paucity of raw material, causing the necessity of keeping large stocks blocking up a considerable amount of capital. Moreover the land prices of industrial areas have recorded an unprecedented increase. The cost of stores, dyeing materials, labour and taxation has shown considerable rise. The cotton mills in the NE-CMD were originally set up with specialised equipments for the production of dhoties and sarees. Restriction on the production of mill-made dhoties upto 60 per cent of the total production, to ensure a proper market for handloom products, poses a considerable threat to their further expansion.

In future locations of new factories, the cost structure should be carefully evaluated. After all, the huge growing market provided by the whole of the CMD is the most important single factor for the location of newer cotton mills within this area. The prospect of this industry happens to be, therefore, bright

Miscellaneous Textile Group of Industries

Excepting cotton and jute, miscellaneous textile group includes silk and woollen mills, lace mills, knitting mills, cordage rope and twin industries, cotton grinning, jute presses and the like. These are small scale industries and are entirely market-oriented.

The Engineering Industries

The Engineering group of industries is one of the most important industries of the NE-CMD. This category includes general engineering like fabrication of basic metals, foundry and machine shops, manufacturing of tea, textile, sugar, cement, paper and other industrial machinery, machine tools and manufacturing of transport equipments like automobiles, bicycles, railway workshops etc., engineering products ranging from road rollers, sewing machines, collapsible gates, nuts, bolts, pipes and tubes, sheet metals and re-rolling mills to razor blades and enamel ware. As this group is marked by diverse branches the problems are also diverse in nature. This group is absolutely market-oriented and presently rationalisation is the crying need to stand competition in the market.

The Chemical Industry

It happens to be one of the dominating industries in the industrial superstructure of the NE-CMD. The area is noted for its wide range of heavy and fine chemicals as well as pharmaceutical products which include items like sulphuric and hydrochloric acids, super phosphates, caustic soda, chlorine, aluminium sulphate, calcium carbonate, industrial explosives, coal gas by-products, rubber chemicals, resin, polythene, cellulose, synthetic antibiotic and other drugs. In order to achieve an overall efficiency, economy of production is of vital necessity. Recovery and fuller utilisation of by-products can cut down the cost of production to a great extent.

Paper Industry

Of the six paper mills in West Bengal, four are concentrated in the NE-CMD. In fact, the region produces more than 15 per cent of all India total. Paper mills have been there since the early days of paper industry in India. Market, the single most important factor governing the development of the industry, is highly developed. Rising cost of production is now a threat to the industry which has failed to keep pace with the changing techniques of production.

Miscellaneous Industries

The NE-CMD can take pride in having the first Glass Factory of India. This area has got one factory-scale unit of soap manufacturing at Baranagar and a number of cottage-scale units, catering mainly to the local needs. Two big units and a number of small units of paints and varnishes enrich the industrial landscape of the NE-CMD. Though devoid of any big unit of manufacturing, the NE-CMD has got a number of small units representing the rubber industry. The leather industry consists of 68 small-scale chrome tanneries, employing about 3,000 persons and is fairly well developed.

Food stuff, beverage and tobacco together form what is called agro-based industries, absorbing about 12,500 persons. The major constituents of the wood and wood products group of industry in the NE-CMD are match factories, saw mills, ply wood factories and units making wooden furniture. Of these the match industry has a national importance producing 15 per cent of the national total. Calcutta with all its educational, cultural, commercial and administrative activities and also the presence of numerous schools, colleges, industrial organisation in the NE-CMD itself has given rise to a highly developed printing and publishing industry, consisof 55 units and employing nearly 1000 persons.

Bricks and tile making, laundries, ice factory, button making, pencil making, plastic articles constitute what is called the Miscellaneous Group of Industry which meets mainly local requirements.

CONCLUSION

After this analysis of the industrial superstructure, a cursory glance at the overall situation may be of interest.

In any appraisal of the prospect of the manufactured activities of the NE-CMD some bottlenecks and impediments are too serious to be ignored. Limitations of space for spatial expansion particularly in industrial zones necessitate fuller utilisation of the installed capacity. The unplanned agglomerations happen to be a serious hindrance to the growth of industry. But a solution to the problem is not so easy because industries and settlements have mainly grown on the Hooghly levee beyond which lie marshy lowlying tracts which are subject to waterlogging during the rainy season. Deterioration of the Calcutta Port poses a serious threat to the very existence of this segment of the greatest industrial cluster of India. But this problem is likely to be solved after construction of the Farakka Barrage. Whatever drawbacks there may be, there is no reason to become pessimistic about the industrial future of the NE-CMD, specially in view of the availability of labour in fair abundance, scope of industrial diversification and the prevalence of keen competition.

IMPORTANCE OF THE SUNDARBANS REGION IN WEST BENGAL'S ECONOMY

RABINDRA KUMAR SENGUPTA

Abstract

The Sundarbans Region lies at the southern end of the Ganga delta. It is one of the most fertile areas in the State. Yet due to some problems it has become one of the most neglected area in the State. The area has a great potentiality in respect of its resources and if it is properly planned for the development it can support the State economy to a great extent.

The area at present is a monocultural area, producing only rice as the principal crop. Soil salinity is one of the serious problems of agriculture. Moreover in the absence of sweet water supply and lack of good transport system, marketing of the agricultural products which have a vast market in nearby Calcutta Metropolitan District is a serious problem. Next to paddy, fishery and animal husbandry are important.

During the plan periods the State registered an overall increase of population, whereas due to negligence, the Sundarbans Region failed miserably in this respect. The population in the CMD as also of Haldia, Asansol and Durgapur Regions, are expected to increase at a tremendous rate and it is necessary to develop the Sundarbans Region in such a way so that it can meet the demand of food supply for the vast multitudes in the growing urban areas.

Proper planning for the development of this area is badly needed. Some projects on irrigation, for desalinisation of the area and for the improvement of embankments etc. are at present under study. It is necessary now to prepare a Regional Development Plan for the area and to put it into operation so that the Sundarbans area can support the State's economy to a great extent.

The Sundarbans Region lies at the southern end of the Ganga delta. It is one of the most neglected areas of the State, the area, if with proper measure the problems can be tackled, can benefit the economy of the State to a great extent. Nowadays much attention has been paid to this area for the development and in this paper I will try to give a brief account of the present-day conditions, its resources and problems and the need for planning in this region in respect of the growth of the State's economy.

PHYSICAL BACKGROUND

Physiography

The present area is bounded by the river Hooghly in the west, Bangla Desh to the east, the sea on the south and a line named Dampier-Hodges Line, marks the northern limit of the region, comprising an area of 3089 sq. miles. It was in a wild and uncultivated state two centuries ago. Nearly half of the area, 1460 sq. miles have been reclaimed by constructing 2200 miles of embankments. The area, criss-crossed by numerous rivers and channels, among them Hooghly, Saptamukhi, Thakuran, Matla, Gosaba, Raimangal etc., the large rivers all flowing from the north-south direction, are connected by innumerable tidal creeks and channels forming a network of drainage pattern in this region. All the rivers are guarded by embankments which are built to protect the surrounding cultivated lands from the inundation of saline water. Thus the construction of embankments around the rivers makes the area 'a saucer-shaped topography' which is one of the problems in respect of drainage disposal in this region.

Climate

The area enjoys a salubrious climate throughout the year on account of its location on sea shore. The temperature changes from 20°C in Dec-Jan. to 28°C in June-July, the average rainfall is 180 cm of which the highest amount occurs in the month of September. Cyclonic storms are common in May accompanied by high tides which cause serious breaches in the embankments and devastate the life and property in the region.

Soil

On the basis of soil survey it has been found that clayey soil is predominant. Others are loamy and sandy soils. Soils are saline in northern and central parts of the region, saline alkali in southern region. A pocket of non-saline alkali region is also found in Mathurapur area. The clayey soil is suitable for the cultivation of *patnai* variety of rice which is one of the most salt tolerant crop in this region.

Landuse

The area is predominantly agricultural. The NSA is 72 per cent. Nearly all the lands which are available are brought under cultivation. The area is a monocultural area and only paddy is important which constitutes 97 per cent of the total crop produced in this region. Due to the absence of irrigation and saline nature of the soil double cropping and other crop cultivation is not possible.

RESOURCE POTENTIAL

Population

The total population in the region in 1961 was 1,532,102 of which 97 per cent lived in rural areas. Density is 739 persons per sq. mile. Highest density is found in NE corner of the region. At first the region was covered and reclamation began and with gradual introduction of cultivation human settlements came to be established and as a rule the population is composed of migrants who came mostly from other districts of the State. Scheduled castes and tribes are predominant in NE region. After the partition, displaced persons from (Bangla Desh, formerly E Pakistan) also settled in this area. As a rule the population increased by over 42 per cent during a decade, which is too high in respect of the State as a whole which barely shows 32 per cent for the same period. Regarding occupation nearly 86 per cent is under primary sector pointing out that the only occupation the area can offer is agriculture There is scarcely any industrial enterprise as the secondary sector could absorb only 2 per cent ; the rest are in tertiary sector.

Livestock

From the information collected from Directorate of Animal Husbandry, Govt. of West Bengal, it has been found that cattle are predominant in this area consisting 2/3 of the total number of beasts followed by goats which are 50 thousand. Buffaloes and sheep constitute 5 per cent only. Nearly 1.66 lakhs of ducks and fowls are found here, distribution ratio between them is two to one. Milch animal represents 34 per cent of the total female beasts in the area Though the she-buffaloes' number is less than the cow yet the production of milk is little over three times that of the cow's milk and this is due to the disparity of yield rate of these two categories of animals which is, a cow gives 0.95 kg of milk per day whereas a she-buffalo yields about 3 times as much i.e. 2.712 kg. per day.

Fisheries

According to the Pantulu Report of the Central Inland Fisheries Research Institute, Barrackpore, nearly 3200 metric tonnes of sea fish are reported to be the annual output in the lower Sundarbans Region, which is increasing by about 20 per cent since 1960-61. There are eight landing centres of which Kakdwip, Namkhana, Hasnabad, Diamond Harbour etc. are important. The most important assembly centre is Namkhana where annual landings are found to be 782.6 metric tonnes

Except occasional seasons, of *Hilsa.* about 80 per cent of the landings is composed of varieties which are unfamiliar dish amongst the middle class consumer and have no good market value. However, it has been ascertained that varieties such as *vetki. chanda, topsia,* readily preferred in Calcutta markets, are found in abundance in this estuarine region. So the development plan for those types of fishes which have good commercial value is important and improvement of transhipment system to Calcutta and its suburbs is also equally important.

The seasonal nature of the occupation attracts few people in this trade. The main fishing season is from November to February while the remaining eight months become dull period. Most of the fishermen engaged in fishing in this region come from outside the area in fishing season and afterwards they leave the place. Moreover the eternal problems such as money lenders, *aratdars* and lack of capital and equipments, better organisation etc. are also responsible for the problems in fisheries in this region. A plan seeking improvement of the trade is essential, which will encourage the fishermen to launch deep into the zones of good quality of fish.

Forest

The present area of forest is 1646 sq. miles lying at the south eastern part of the region, an area traversed by a close network of rivers, channels and creeks. Due to the persistent efforts backed by strong demand for food, gradually led to strip the precious forest areas of its present state There are 40 different species of trees and shrubs of which *goran*, *keora*, *sundri*, *hintal*, *golpata* etc. are important. However *sundri* appears in the higher lands where the area is less susceptible to salt water inundation. According to the information collected from office of the Chief Conservator of Forest the region has average annual growth of 7 cft. of timber per acre, the present stand of timber is estimated at 40.32 million cft. The stock of firewood is calculated at 69.12 million cft. The mean annual increment of firewood is known to be 12 cft. per acre. The timber is of poor quality and firewood is important. It is reported that during the 3 years from 1962, 1963 to 1964-65 the forest yielded an average annual revenue of Rs. 6.58 lakhs which accounts a rate of a rupee per acre, and is very poor indeed compared to that of other forest areas of the State. It is necessary to establish a direct economic relation between the forest area and other parts of the State for as long as the demands for forest products to the neighbouring areas is negligible, the standard of exploitation of the Sundarbans forest cannot be hoped to be raised and the revenue will therefore continue to be poor. In this respect the installation of paper or board industries should be set up in a neighbouring zone where the forest products could be utilised as well as will encourage the exploitation of the forest to its full potential.

According to the experts, the trees such as *goran*, *keora* etc. which are suitable for pulp making are also useful source of tannins as well. In West Bengal the tannin industries require one lakh maunds of tannins per year and the Sundarbans can meet the supply to a great extent.

At present 3000 mds of honey are produced and if suitable canning and market facilities are arranged the production can be increased manifold and this region may make best of the opportunity and encourage the export of honey.

THE NECESSITY FOR A REGIONAL DEVELOPMENT PLAN

So far we have observed that this region has a great potentiality but due to negligence this area suffered much. which can contribute to a great extent if proper care be taken. It is important to develop the area immediately for which some reasons can be cited which are most important in respect of the State's economic position.

The trend of population in West Bengal is increasing at a tremendous rate which will be almost double its present population in 1986. It has been estimated that 70 million heads will reside within an area of 33 thousand sq. miles. But the scanty extent of the cultivable land is causing serious concern. At present the State has already been obliged to import a quarter of its annual requirements of food grain from outside and unless the notable increase of agricultural production occurs the situation may worsen to the stage of a real crisis. In this respect almost all the districts have used their respective cultivable land and offered little scope for extension. The Sundarbans Region provides some hope in this respect provided certain related problems are resolved.

The area was known as granary of the Metropolitan District and alone supplied the necessary food requirements before the First World War and functioned as a complementary unit and remained virtually linked up with the Metropolis for long, but in recent times the situation changed. As the post-war developments led to increase of population in Calcutta industrial region, the Sundarbans *abad* area on the other hand failed miserably in this respect due to negligence.

According to the Basic Development Plan for the CMD published by CMPO it has been pointed out the magnitudes of the future requirements of food items for its projected population. It is certain that unless a Regional Development Plan for the Sundarbans is prepared with due objectives it would be extremely difficult to meet the future requirements and in this respect the Sundarbans area with its present resources would be able to fulfil a major need if proper development takes place in due time.

PLANNING FOR THE CALCUTTA METROPOLITAN DISTRICT 1966-1986

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Abstract

This paper is a review of the Basic Development Plan (BDP) for the Calcutta Metropolitan District, 1966-86, which was formulated during 1965-66, and points out the defects in the BDP which were due to limitations of the objective situation and also of the subjective understanding of the planners. It gives a resume of the new in the current situation which has necessitated a revision of the BDP. The current economic situation is marked by a decline in industrial employment, decline in Calcutta Port traffic, transformation of the engineering goods into a minor exporter, unfavourable price balance for industrial goods after 1966 and political instability. This is the darker side of the picture. The brighter aspects include breakthrough in agricultural technology, availability of a sizeable amount of public fund for Calcutta area development, development of a new port of Haldia, near completion of the Farakka Project and initiation of some industrial incentive schemes. The paper suggests that the basic strategy for an economic development programme for the CMD should centre round the four facets of industrial development, viz., (a) utilisation of existing capacity, (b) creating new capacity, (c) specifying the appropriate location and (d) developing the new infrastructure. The strategy of Metropolitan Planning will have to be designed with the overall developmental objective of our State and the nation as a whole.

The Basic Development Plan (BDP) for the Calcutta Metropolitan District, 1966-86 was formulated during 1965-66. It was the first ever metropolitan plan in our country which not only conceived Metropolitan Plan as an integral part of the overall Regional Development Plan, but also tried to tackle *simultaneously* the problem of economic-cum-social development and physical development, and the problem of short run relief along with long run remedial-cum-development measures in one policy frame. On the basis of a comprehensive analysis based on the then level of understanding of the different facets of the Metropolitan situation in its regional setting, it selected the following five major fields of planning activity in the Metropolis :

(i) Economic Development, (ii) Water

Supply, Sewerage and Drainage. (iii) Traffic and Transportation, (iv) Shelter and housing, and (v) Education.

Amongst the above five major fields, again, BDP was explicit in its understanding that "the economic problems lie at the root of most of the problems which beset the Calcutta area and its immense hinterland[1] and the very first of the four objectives of the plan was. "To promote a more dynamic growth of the Metropolitan Economy with increased production and income, with sufficient employment opportunities and with close integration with the economic development of the region for which Calcutta provides vital economic functions."[2]

The above was a demonstration that comprehensiveness in practice leads not only to selectivity but also to the identification of key or the central problem from amongst the selected problems. All other problems of the Metropolis either can be solved or depend for their solution on the solution of the selected problems. This was definitely a big step ahead in understanding comprehensiveness in practice.

Not only in terms of sectors, but also in terms of spatial development within the Metropolis, the Plan exercised a selectivity. It focussed its attention on two major areas within the CMD, viz. (i) the Metropolitan core embracing Calcutta and Howrah cities and their immediate suburbs, and (ii) Kalyani-Bansberia area at the northern tip of the Metropolis. In terms of concentration of existing problems, and also in terms of lack of utilisation of productive resources, the former area is without any parallel, and hence for concentration of immediate relief, for checking further deterioration as well as for utilising fully the existing resources, the former area was recommended for focussing priority attention. And the latter area, because of its physical locational advantage vis-a-vis the entire hinterland, and several other physical advantages, was considered unique for concentration of new long term developmental activity. This area selectivity was, thus, the logical corollary of the principle of combining immediate relief with long term developmental needs.

Despite this understanding of the BDP when it came to recommend projects, the economic development projects were conspicuous by their absence. This crucial discrepancy between the results of analysis and specific recommendations of schemes arose due to various factors. Firstly, when the new understanding reflected in identifying economic development as the key to all other development was being developed during 1965-66, the list of schemes, prepared in connection with framing the Fourth Five Year Plan and presented to Government in a printed Memorandum in early 1965, was already existing as a given reality. Secondly, by the very nature of the BDP it had to confine itself to basic concepts, to identifying basic direction of movements only. And that is why the BDP recommended preparation of five functional plans, covering the five selected fields mentioned

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1. BDP for the Calcutta Metropolitan District, 1966-86, p. 21.
2. Ibid. p. 6.

earlier, on the basis of the policy plan formulated by the BDP. Pending the finalisation of all, the five functional plans, BDP included within the plan document the schemes submitted to Government earlier. If all the five functional plans could be prepared, then the lop-sidedness of the groups of schemes could have been eradicated and a more balanced set of schemes could have been prepared. But as we know all the five sectoral plans were not prepared. Only two viz. (i) Water Supply and Sewerage and (ii) Traffic and Transportation, which were already in advanced stage of preparation when BDP was being formulated, were completed. By the very nature of the process through which these two plans were prepared could not but put an indelible mark of their product as mainly purely sectoral plans Thirdly, the need to incorporate the already existing schemes, even if they did not correspond to the basic principles of the BDP, introduced several inconsistencies and contradictions within the BDP itself. Of the several examples on this point, one may mention the simultaneous emphasis BDP paid on the previously mentioned two-centre concept (Metro-core and Kalyani-Bansberia) and also on some other growth centres such as Sonarpur, Tollygunge-Panchannagram, Behala etc. The internal inconsistencies provided excuses to justify almost any area development project in the name of BDP. Fourthly, due to an unwarrented fear of rigidity associated with the term "Master Plan" or an undue eagerness to provide flexibility made the framers of the Plan refrain even from recommending the preparation of physical plan for the metropolis which would have had provided the physical frame work for integrating the different schemes in space and to judge the appropriateness or otherwise of the specific schemes. This absence of a physical plan further reinforced in practice the isolated, sector-orinted or an isolated area-oriented 'planning' mentioned earlier, which was, in a way, just the opposite of comprehensive planning which BDP sought to advocate. And lastly, the resource availability even for implementing the relief schemes became more scarce after 1966. It was in a way highly unfortunate that the publication of BDP coincided with 'plan holiday', with drastically reduced public sector investment, with an unprecedented recession in our economy, coupled with an element of instability in the political structure. While the need for planning increases with the increase in resource constraints, in the absence of appropriate leadership, CMPO failed to respond to this new situation by vigorously pushing forward its activity on comprehensive plan preparation. And so the concretisation of planning policy directives contained in the BDP could never really be attempted in practice.

All the defects mentioned above arose not only from the objective situation but also from the subjective limitation of understanding of the planners. After 1966, however, there occurred some crucial change in the objective condition itself and these have made a radical revision of BDP still more necessary. Despite the failure to continue the comprehensive planning exercise, CMPO, however, did provide in this period some essential services to the State in the sphere of economic analysis and planning field by preparing Report on Engineering Industry of West Bengal in 1967-68 on behalf of the Survey Committee on Engineering Industry appointed by the State Government for suggesting remedials to the recession in Engineering Industry. Similar reports were prepared on jute on behalf of the Commission of Inquiry on Jute Industry appointed by the Government of West Bengal The other significant fields with implications for economic development where work was undertaken in the CMPO were: preparation of District Development Plans[3], fiscal resource mobilisation plans for the State as a whole, and plan for augmentation of Municipal resources for all the Municipalities of West Bengal. Several other studies have also been made having relevance for economic planning in the CMPO. It is these studies which have further sharpened our understanding as to what need be done in the economic field in the CMD and in West Bengal in the new situation that has arisen after 1965-66.

Based on these additional analysis and understanding of the economic situation in West Bengal, and a new hope arising from the availability of finance to implement the already prepared CMD area improvement schemes, an picture attempt has been made here to present a of the current economic condition in the CMD in the background of West Bengal, and of what can now be done to initate and to sustain a basic change for the better.

THE NEW IN THE CURRENT SITUATION

The main elements in the new situation

The most important new developments which have adversely affected the CMD and West Bengal are :

(i) Industrial employment decline : From moderate rate of increase upto 1965 to rapid decline since 1965.

(ii) Decline in Calcutta Port traffic : From stagnation upto 1965-66 to rapid decline after 1966.

(iii) Transformation of the dominant exporter of engineering goods upto 1965 to a relatively minor exporter since then.

(iv) A change from a relative price balance between industrial and agricultural products upto 1965 to an unfavourabalance for industrial goods after 1966.

v) A change from a stable political Government structure upto 1966 to an unstable and rapidly changing political complexion of the Government since 1966.

vi) A substantial increase in labour-management dispute.

There, however, have occurred some welcome changes also. Of these, the following may be noted :

i) A break-through in agricultural technology creating a possibility of a rapid rise in agricultural production and employment, which may affect favourably industrial and metropolitan development also.

ii) Availability of a sizeable amount of public fund to carry forward a rescue operation in the Calcutta area denoting a national awareness about the problems of the Calcutta area.

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[3] One for Burdwan District is already complete and two others are in the process of preparation.

iii) Development of a new port and industrial complex at Haldia.

iv) Near completion of the Farakka Project firmly linking up south Bengal with north Bengal and providing possibilities for bringing fresh water near Calcutta and for checking further deterioration at the Calcutta Port and also for maintaining the navigability at the Haldia Port.

v) Initiation of some industrial incentive schemes, 16 points programme, formation of Industrial Reconstruction Corporation Ltd, with Head Quarter at Calcutta, reorganisation of West Bengal Industrial Development Corporation, initiation of Small Farmer Development Programme (SFDA) and that for Marginal Farmer and Agricultural Labourer (MFAL) etc, and

vi) The emergence of Bangla Desh as a sovereign State with a very friendly relation with India and West Bengal.

It is now necessary to give a short resume on each of the aspects noted above.

Industrial Employment : Growth to Decline

From 1953 to 1965 there had been a consistent increase in employment from year to year in the registered factory sector and even if the rate actually achieved (4.6 per cent per annum compound)during the last five years of that period continued after 1965, then the employment should have been 921 thousand in 1966, rising to 1054 thousand in 1969. In actual reality, however, an absolute decline started after 1965, and actual employment in 1966 was 840 thousand i.e. 8.8 per cent less than the expected volume, and in 1969 the actual employment was 791 thousand i.e. 25 per cent less than the corresponding expected value. In 1970, there occurred an upturn and employment increased by 18,000 compared to 1969. But this increase was entirely due to increase in employment by 20,000 in the jute industry and as such, the decline in employment in the non-jute sector continued even in 1970.

It may also be noted that this absolute decline in employment was essentially a West Bengal phenomenon, because in the rest of India, registered factory employment did increase after 1965, although at a reduced rate. The pattern may be clear from the Table-1.

This growth and decline in manufacturing employment in West Bengal affected most vitally the CMD because nearly 75 per cent of registered factory employment was concentrated in the CMD. As a matter of fact, while the total decline in employment in West Bengal during 1965-69 was by 89 thousand, that for the four CMD area Districts (Calcutta, 24-Parganas, Howrah and Hooghly) was as high as 98 thousand. This means that in the non-CMD areas there occurred a marginal increase in employment even during this period. It may be mentioned that in the previous 4 years, 1961-1965 the corresponding total for West Bengal increased by 162 thousand of which 139 thousand was accounted for by the four CMD area districts.

As the whole of the jute industry employment is concentrated in the four CMD area districts, it may be clear that even in 1970, the employment in that

TABLE—1

Percentage increase in the Registered Factory Employment

Area	Period 1951-1965	1965-1968	1968-1969
West Bengal	+ 35.02	— 7.20	— 1.00
Rest of India	+ 68.10	+ 3.20	(not available)

TABLE—2

Registered Factory Employment fluctuation in different areas of West Bengal, 1951-70

District	Actual employment (in '000)					Increase in employment in '000		
	1951	1961	1965	1969	1970	1951-65	1965-69	1969-70
Calcutta, Howrah, 24-Parganas, Hooghly	567	600	739	641	652	+ 172	— 98	+ 11
Other Districts	85	118	141	150	157	+ 56	+ 9	+ 7
Total : West Bengal	652	718	880	791	809	+ 228	— 89	+ 18

area in the non-jute sector declined by 9000.

The relatively much higher intensity, with which the post-1965 all India industrial recession had hit West Bengal, was due to, amongst others, the nature of industrial mix of West Bengal and CMD. The two major industries which dominate CMD are Engineering and Jute. It is a welcome fact that a *basic* change has occurred in the structural mix of the CMD (hence of West Bengal) manufacturing industry during the planning period. This was reflected in the fact that jute gradually gave way to the engineering as the most dominating industry in the metropolis and in West Bengal. The pattern may be clear from the Table-3.

While noting the gradual rise of the engineering industry to the dominating position in West Bengal, it may also be noted that by far the most severe impact of recession, from the point of view of employment, was on jute industry. Thus, of the total decline in employment during 1965-69 by 89 thousand, the share of jute industry was 55 thousand (or 62 per cent of the total) and that of engineering industry was 29 thousand (or 33 per cent of the total), and that of all other industry together was only 5 thousand (or less than 5 per cent of the total). And the rate of decline in employment during 1965-69 in the engineering industry was 2.3 per cent per annum (compound), the corresponding rate for jute industry was much higher 5.7 per cent per annum (compound). It may also be noted that during 1961-65, the rate of growth of jute industry employment[4] was nearly equal to that of the 'growth industry', the engineering industry. And, during

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[4] 6.5 per cent per annum (compound).

TABLE—3

Registered Factory Employment in different industry groups, West Bengal, 1951-1970

(in thousand)

Industry Group	Year				
	1951	1961	1965	1969	1970
Engineering	158	250	324	295	294
Jute	278	202	259	204	225
Others	216	266	297	292	290
Total	652	718	880	791	809

1969-70, jute was the only industry in which employment increased. This may make it clear that, despite the overall loss of dominance, even now the jute industry brings in by far the highest amount of instability in the industrial employment scene of the CMD and West Bengal.

It may sound strange that while one of the main causes of the difficulty of jute industry, arises from its dependence on agriculture, that for the engineering industry, in a way, arises from its lack of any dependence on the agricultural sector. It is, however, not agriculture as such, but its extreme technological and institutional *backwardness*, that prevents an adequate and assured supply of raw-jute and this is one of the major but controllable causes of the fluctuation of its fortune. It is this backwardness of agriculture again which makes it a poor market for industrial goods—both for inputs to be used in agricultural production and also for finished consumer goods which could have been demanded by an affluent peasantry. Compared to more than 25 per cent for the advanced countries, the industrial inputs constitute less than 3 per cent of the value of agricultural output in our country. This may give an indication as to how poor a market our agriculture is for the industrial goods. It may be remembered that the recession in the engineering industry in 1966 got expressed as a crisis of lack of market. And even today, when lack of raw material appears to be the more active cause of sluggishness in growth, lack of market remains a more dominant factor, although to some extent potentially.

The post-1965 recession clearly shows what was wrong with our economic structure and also what was wrong with our understanding of that economic structure. In a nutshell, this relates to imbalance between industry and agriculture, between attempts to develop advanced industry and keeping agriculture at a backward state, between isolated metropolitan planning for growth, and regional, rural *status quo* for stagnation and decay. We shall have occasion to deal more on this topic in subsequent sections.

Calcutta Port : from stagnation to decay

The way BDP presented the importance of the Calcutta Port by mentioning that in 1964 it tackled 42 per cent in India's exports and 25 per cent of India's imports may create a wrong impression about the present role of the Calcutta Port in our Nation. Table-4 gives the amount of goods handled by the six major ports in India during our First three plans.

TABLE—4

Amount of goods handled by the six major ports in India

in '000 tonnes

Year	Calcutta	Bombay	Madras	Vizag, Cochin, Kandla	Total
1951-52	9,736	7,600	2,190	1,988	22,514
1956-57	8,860	12,172	2,500	4,098	27,639
1961-62	9,302	14,548	3,468	—	—
1965-66	9,848	18,197	4,800	14,855	47,700
Percentage increase 1951-52 to 1965-66	1.15	139.43	119.18	397.16	111.87

It may be seen from the Table-4 that volume of goods handled in the other 5 major ports of India, e g. Bombay, Madras, Vizag, Cochin and Kandla increased from 12.8 million tonnes in 1951-52 to 37.9 million tonnes in 1965-66 i.e. nearly by 3 times, while that for Calcutta remained practically static. Calcutta handled in 1951-52 more than 43 per cent of the total goods handled by the six major ports. This share came down to only 20.6 per cent in 1965-66. The tonnage handled by the Calcutta Port in 1964-65 was abnormally high : 11.06 million tonnes. And it may be mentioned that in 1969-70, the Calcutta Port handled only 6.9 million tonnes, i.e. only 70 per cent of what it tackled in 1965-66. In 1970-71, it came down to 6.01 million tonnes and it is reported that in 1971-72 it came down further. The decline in inland vessel traffic is also spectacular : from more than 6 lakh tonnes in 1967-68 it came down to 3.85 lakh tonnes in 1970-71. Again, during the last ten years, 1959-60 to 1969-70, the maximum number of ships entered the Calcutta Port in 1963-64, and the number was 1,828. In 1969-70 it came down to 1,237, a decline by nearly 33 per cent compared to 1963-64. The pattern may be clear from the table below.

Year	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
No of ships entering Calcutta Port.	1,828	1,807	1,623	1,640	N.A.	1,400	1,237

It may be mentioned in this connection that the Report of Haldia Study Team,[5] projected in 1964-65 that the traffic of the Calcutta Port would be 6.8 million tonnes by 1970-71 and this projection seems to have perfectly tallied with the actual reality. However, the Report, submitted in August, 1965, visualised that the total tonnage to be handled by Calcutta-Haldia complex would be 20.6 million tonnes of which Haldia would handle 13.8 million tonnes. With Haldia yet to become an operational Port, the Calcutta Port thus handles now only about one-third of the cargo it was expected to handle and this expectation was expressed by the highest authorities on this subject only 5-6 years back. This, in a way, expresses the depth of the present crisis in the Calcutta area and our inability to grasp the real causes for the present crisis.

It need be emphasised that given the present rate of technological progress in ship-building and the likely condition of the river Hooghly near the Calcutta Port, even after the completion of Farakka Barrage, Calcutta Port will have to convert itself into a port of general cargoes which are handled in relatively smaller ships. And the major port in the Eastern India will be Haldia, and not Calcutta. This is a fact of crucial importance for the development plan for the CMD and also for further acceleration of the developmental work at Haldia and at Farakka.

Dwindling share in export field

Calcutta Port is mainly an Export Port and its main exports are jute manufactures and tea. And export possibility of both these goods are declining and it has declined sharply after 1965. This may be clear from the Table-5.

It may, thus, be seen that the earning from the main commodities which the Calcutta area exported declined by more than a quarter during the four years since 1965-66.

This decline in traditional exports was to some extent compensated by increase in non-traditional export, mainly export of engineering goods, in India as a whole. This shift from backward low value added agro-industry commodities to relatively high value added engineering goods is a very welcome transformation in the mix of export goods. But the Calcutta area could take only a relatively small advantage from this shift. This was primarily because the Calcutta area engineering industries were not at all export-oriented. This has been reflected in the Table-6 giving the shares of different regions in the export of engineering goods (excluding iron and steel).

It may be clear from the table that while engineering export for the country as a whole increased by Rs. 868 million i.e. by 291 per cent the same for the Calcutta port increased by only Rs. 44 million, i.e. by only 23 per cent. Calcutta's share in the total increase in engineering export during 1965-66 to 1970-71 was as low as only 5 per cent.

Thus, so far as the Calcutta area is concerned, the decline in traditional exports has not been balanced by an increase in nontraditional export. And

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[5] Dr. V. G. Bhatia, the then Director of Transport Research, Ministry of Transport, Govt. of India, was its convenor.

TABLE—5

Volume of Exports from India

(in million dollar)

	1965-66	1969-70	Percentage change 1965-66 to 1969-70
Jute Yarn and manufacture	384.9	275.5	— 28.4
Tea (black)	216 2	166.0	— 23.2
Total (Jute and Tea)	601.1	441.5	— 26.8

TABLE—6

Share of different zones in Engineering Export

Period	Calcutta	Bombay	Delhi in per cent	Madras	Total	Total volume of export (in million Rs.)
1965-66	66	23	9	2	100	298
1966 67	49	27	15	9	100	311
1967-68	29	46	18	7	100	415
1968-69	42	34	16	8	100	850
1969-70	25	43	22	10	100	1,064
1970-71	22	51	15	12	100	1,166

that is why the market for the Calcutta area industries as a whole is declining.

Relative price level moves against industrial production, against CMD

The base of the CMD economy is its manufacturing sector. Even the direct income generated by its manufacturing sector constituted in 1961 about 60 per cent of the total income generated in the area. There is no reason to suspect that this proportion has been basically altered.

The primary basis of this industrial economy is cheap supply of raw material, and food which enabled it to reduce the cost of inputs and of wage. And this base was hit hard particularly after 1965 when the price of raw material and of food increased at a relatively much higher rate compared to that for the manufactured goods. The pattern may be seen from the Table-7.

It may be seen from the Table-7 that the rate of increase in price was highest in the period following 1964-65, and the absolute differential in the relative levels of prices between the manufactured goods on the one hand and the prices of raw material and food on the other also was highest during that period. A rise in the price of the raw material without a compensating rise in the price of finished goods tends to lower the relative level of value added (income) from the manufacturer of finished goods. And a relatively very high rate of increase in the price of food articles meant

TABLE—7

Annual average percentage increase in price level in Calcutta for the commodity

Period	Food article	Industrial raw material	Manufactured finished produce
1952-53 to 1961-62	2.3	6.0	2.4
1961-62 to 1964-65	5.8	1.5	0
1964-65 to 1968-69	13.7	15 0	7.8

that the need for higher wages also increased proportionately. Unfortunately when the need for higher wages rose, the relative capacity of the manufacturer to pay higher wage declined. As a matter of fact, the total real wage bill for factory workers (with 1960 as base) did go down after 1965 both in West Bengal and in India as a whole despite a substantial increase in money wage bill, as may be clear from the Table-8.

The same phenomena may also be seen in terms of per capita daily earning of the above group of workers Table-9.

This, along with a rapid fall in employment discussed earlier, is the objective basis of the fierce labour-management trouble that arose during this period and which has further accentuated the recession in our economy. It may further be mentioned that the real wage level in West Bengal (i.e. in the CMD) is far lower compared to all the three other major centres of industry, in our country viz. Maharastra, Tamilnadu and Gujarat as may be seen from below :

Per capita real wage of the above group of workers, 1968

	Rs.
Maharastra	5.47
Gujarat	5.03
Tamilnadu	5.01
West Bengal	4.50

It is necessary to point out here that, contrary to popular belief, the rise in prices for agricultural goods, particularly food, which harms industty and urban consumers, does not benefit at least 75 per cent of the peasant who either do not

TABLE—8

Total wage bill of factory workers earning less than Rs. 400 per mensem

(in million Rs.)

	West Bengal		India	
Year	Money wage bill	Real wage bill	Money wage bill	Real wage bill
1965	1,244	972	6,397	4,669
1966	1,276	886	8,792	4,498
1967	1,380	868	7,132	4,176
1968	1,539	900	7,859	4,440
Percentage increase 1965-68	+ 23.7	— 7.4	+ 22.8	— 4.9

TABLE—9

Per capita daily wage of factory workers earning less than Rs. 400 per mensem

(in Rs.)

Year	West Bengal		India	
	Money wage	Real wage	Money wage	Real wage
1961	4.69	4.64	—	—
1965	5.99	4 68	6.16	4.50
1966	6.61	4 59	6.70	4 41
1967	7.21	4.53	7.24	4.21
1968	7.69	4.50	7.73	4.37
Percentage increase 1965-68	+ 28.4	— 3.3	+ 25.5	— 2.99

own any land or own very little. This is so because they are not net sellers but net purchasers of food. The main profit from transaction of agricultural goods goes to a tiny stratum of rich peasant and speculative commercial units. And it is these speculators who benefit not only at the cost of most of the peasants and workers, but also at the cost of manufacturing production.

The way post 1965 price level for agricultural and manufactured goods changed gave rise to a very interesting phenomenon in the West Bengal economy. In 1951-52, income from agriculture in West Bengal (Rs. 257 crores) was 1.760 times higher than the corresponding income (Rs. 146 crores) from the manufacturing sector (factory plus small units). The income level in 1966-67, at 1951-52 prices, for agriculture was Rs. 351 crores which was only 1.026 times higher than the corresponding manufacturing income of Rs. 342 crores. But due to the differential in price rise, agricultural sector received as much as Rs. 702 crores in 1966-67 at current price and it was higher by 1.902 times of what was received by the manufacturing sector. The same phenomenon is continuing even after the end of drought. Thus, in 1969-70, agricultural output, at 1951-52 price, was valued at Rs. 394 crores and it was higher by 1.22 times the corresponding value of manufactured output (Rs. 323 crores). But at current price, the corresponding differential is as high as 2.15 times. Thus, particularly since 1965, a tiny upper stratum in the agricultural sector has been robbing the manufacturing sector as well as the overwhelming majority of our population both during drought or during bumper crops, through the prevailing price mechanism. The pernicious effect of this mechanism on the manufacturing sector, on the metropolis, as well as on the 75 per cent of the peasant families can well be imagined.

From Political stability to instability

The political complexion of the West

Bengal State Govt. remained the same throughout the post-independence period upto 1967 i e. for twenty years, and it was identical with that of the Central Government. But in the four years, 1967-1971, the political complexion of the State Government changed six times and few times it was not in line with that of the Central Govt. How this has adversely affected the administration and the tempo of developmental effort during these years are well known.

By far the biggest casualty of this political uncertainty was the planning and implementation effort for Calcutta development. As mentioned earlier, this instability started just when the Calcutta Metropolitan Planning Organisation, CMPO, was on the way to develop a comprehensive development scheme on the policy guidelines provided by the Basic Development Plan published in 1966. This uncertainty has led to non-planning in the CMPO, and it fits in well with the mood of national 'plan holiday'. And when almost suddenly development funds became available CMPO was not in a position to provide a multi-sectoral balanced comprehensive development projects, and so the execution had to begin on the schemes, conceived mainly sectorally either without considering the inter-sectoral linkages or considering the spontaneous development pattern of other sectors as given.

Labour management dispute

In 1952, only 95,000 industrial workers in West Bengal got involved in industrial disputes, and the resulting total man-days lost came to 544,000. In 1969, the corresponding figures were 670,000 (more than 7 fold increase) and 9,381,000 (more than 17 times increase) respectively. Looked at from a different angle, in 1952 the number of workers involved in work stoppages constituted only 15 per cent of the total registered factory workers and resulting man-days lost constituted only 0.35 per cent of total man-days of work by these workers, on the assumption that they worked on an average for 250 days per year. The corresponding figure for 1969 was 85 per cent and 5 per cent respectively.[6] The relevant data for the last two decades are given in the Table-10.

The whole of these man-days lost is not obviously due to labour strike. Thus in 1970, 59 per cent of the man-days lost was due to labour strike, while the remaining 41 per cent was due to lockout by management. Moreover, average duration of lockouts (44.9 days) was nearly three times that for strikes (15.4 days). Thus, the management appeared to have fought their battle more stubbornly than was possible for the workers.

Despite the significant increase in the man-days lost during the latter half of the last decade, its highest share in any year was less than 5 per cent of days actually worked. As such, it appears that the prevailing impression that the labour management dispute is one of the major causes of the current recession in industry seems to be not based on facts.

An approximate idea of the man-days lost due to recession may be derived by

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[6] In this calculation, a worker who was involved, say, thrice in disputes during the year was considered as three workers.

TABLE—10

Year	Total No. of Regd. factory workers	Total No. of workers involved in dispute	No. of man-days lost	Estimated No. of man-days workers	(3) as percentage of (2)	(4) as percentage of (5)
	IN THOUSANDS					
1	2	3	4	5	6	7
1952	627	95	544	156,750	15.15	0.35
1961	718	149	2,051	179,500	20.75	1.14
1965	880	124	1,363	220,000	14,09	0,62
1966	840	154	2,754	210,000	18.33	1.31
1967	831	165	5,016	207,750	32.19	3.29
1968	817	263	6,723	204,250	32.19	3.29
1969	791	670	9,381	197,750	84.70	4.74
1970 (prov.)	809	463	9,783	202,250	57.23	4.83

projecting the employment that would have been generated had there been no recession after 1965 and the number of man-days of work that would have resulted therefrom. If the employment in the registered factory sector could grow after 1965 at a rate by which it actually grew during 1961 to 1965 (i.e. at a rate of 5.2 per cent per annum compound), then employment during the five subsequent years would have been 926, 974, 1024, 1077 and 1133 thousands respectively. With the above employment, total man-days worked during these 5 years would have been 261,500 thousand higher than the actual man-days of work done Compared to this estimated loss of man-days amounting to 261 million during 1966-70 due to recession, the amount of man-days lost due to labour management dispute during the same period was less than 34 million (or only 13 per cent of the former). These data clearly reveal that the nature of the crisis in our economy lies much deeper than what may appear to be from the figure of man-days lost due to labour-management disputes. The latter may be taken as a serious symptom of the crisis, and not as one of the main causes leading to the generation of the crisis.

We now move to the next few sections dealing with some of the good features which have emerged during the last few years—the features, if properly used, can lead to a total transformation of the present situation ushering in a new, bright future for our entire people.

Birth of a new agricultural technology : opening up a new horizon.

The most important of these new

good features is the development of a new agricultural technology which can make possible a simultaneous introduction of efficiency and equity in our agricultural sector. And this may have a tremendous positive impact on our entire economy, including, of course, the sagging metropolitan and industrial economy.

Existing backwardness of agriculture, and the various existing socio-economic institution like usury, rack renting, and speculative commerce and non-availability of industrial inputs like power, fertiliser etc. which keep the agriculture backward—are all, in the main, relics of our colonial past. And the port city of Calcutta, and the subsequent industrial-commercial structure that developed around it, also depended upon and, hence in the main, maintained this backwardness. Perhaps the most basic weakness of the BDP was the absence of any analysis of the existing relationship between industry and agriculture, and between the metropolis and the country side and how and why this relationship need be changed for a healthy development both of the Metropolis as well as of its rural hinterland.

The main aspect of the agricultural technology available earlier was based on mechanisation of agriculture, on labour saving devices, wich could best be practised on large plots of land. This was so because these were developed in the West which suffered from labour shortage in agriculture and which had the developed industrial base to supply the tools and machinery for this agricultural modernisation. But the colonial rule over India led to a drastically *increased* population pressure on agriculture, and the heavy industry capable of equipping our agriculture was, of course, not allowed to be developed here. And so, despite some advance in modern manufacturing industry, mainly concentrated on agro-based textile and transport service oriented engineering, in the few urban centres of our country, our rural areas, our agriculture had to remain content with a technology several centuries old and with a population burden which was gradually increasing.

Even after independence, the huge back log of population pressure, a near absence of heavy industry, and also the nature of policy pursued in practice prevented not only the application of the then modern technology in agriculture, but also the abolition of the backward semi-feudal institutions which would have had unleashed at least the creative energy of labouring peasants. And so our agriculture remained backward even after independence. In the meantime, however, a base was laid in our country for heavy industry, for machine making engineering industry for modern chemical industry etc. But due to our backwardness leading to poverty, even the goods that can be or were produced by the engineering and other industries were not 'demanded' by our country. And that, amongst other, led to severe under utilisation of industrial capacity and then to recession after 1965. The immediate cause of the recession was consecutive drought in agriculture in 1966 and 1967, and the inability of the government to continue maintaining its tempo of new investments creating new demands for our industry.

It is in this background that the significance of the latest break through in agricultural technology need be seen and appreciated. High yielding, short duration seeds, if supplied with adequate fertiliser and pesticide, developed during the late 1960's has made highly economic the huge investments that may be required on power for effecting water management and on plants for producing fertiliser and pesticide. Given the wonder seeds, the symbol of this modernisation is not tractor or complete mechanisation of agriculture ; the symbol is efficient water management. And the two most important things about this technology is that (i) it is a labour intensive modern technology, although it may also be applied along with complete mechanisation, (ii) it can be implemented even in relatively small plots of land. The most significant break through has so far been in wheat, and though we have substantially improved variety in rice also, a similar break through in the field is still awaited.

The above two features of the new technology, therefore, can achieve at least a twofold increase in productive agricultural employment and this can solve the most pressing problem of to-day, viz huge unemployment. It can increase dramatically the level of total output, and so also output per acre and output per labour. It has made technologically possible substantial lowering of the economic size of the holding. And this provides the technological basis for lowering the land ceiling to even less than 10 acres which may make possible at least a partial fulfilment of the age-old dream of the poor and landless peasant, viz. to own a piece of land. As per 1961-62 estimates, 96 per cent of agricultural families had less than 10 acres in West Bengal. If the ceiling was fixed at 10 acres, then estimated surplus land which might have been available from them in 1961 would be about 9 lakh acres. This would have had made possible ensuring about 0.45 acres in 1962 to each of the peasant families who had then less than that amount. If the ceiling was fixed at 20 acres, the availability of land to the landless and poor peasants would come down to mere 0.16 acres per family. And if the entire land is distributed equally amongst all peasant households, it may be possible to ensure at least 2 acres of land even to-day. It may be demonstrated that, in terms of order of magnitude, an average family with 1.5 workers can make available 1.5 x 250 or 375 man-days of work per year. Assuming that labour requirement per acre per crop is 70 man-days, no family can cultivate more than 2-3 acres mainly with its own labour. On the basis of 2-3 crops per year the whole working force per family can be kept employed throughout the year with 2 to 3 acres of land. Thus, the families with more than that amount will need to hire agricultural labourer and those with less than that amount will have to hire them out as agricultural labour. Higher the level of ceiling, therefore, bigger will be the problem of guaranteeing an adequate wage to the agricultural labourer.

In terms of providing productive employment opportunity, it may be stated that even if we may achieve 2 crops per year on an average, it will increase the additional *full time* productive employment opportunity for about 2 million persons directly in agriculture alone. Of the other welcome implications for the Metropolis of this agricultural modernisation, the following may be mentioned :

(i) Adequate supply of food and raw material. It will eliminate the need for their imports, make possible adequate supply and lowering of their relative prices. It will thus, solve one of the pressing problems of the urban area in general and metropolitan industry in particular.

(ii) Substantial increase in demand by agriculture for industrial inputs such as fertiliser, pesticide, tubewells, pumps, various tools and implements etc. This will increase significantly the share of industrial input in the total output produced by agriculture from the present level of less than 3 per cent towards the direction of 20-30 per cent which is the prevailing proportion in the advanced countries. This is bound to increase dramatically the size of the market for industrial goods.

(iii) Substantial increase in demand also for industrial consumer goods, increasing further the size of the market. The above two will thus solve another problem of urban metropolitan industry.

(iv) This dramatic increase in the size of the market and its wide extension throughout the country will make it not only possible, but also necessary, establishment of industrial-cum-servicing centres in the existing towns and in newly established growth centres. The costly and inefficient methods of trying to develop artificially rural or dispersed industries primarily on the basis of fiscal incentives can now be replaced with the above. This have a crucial significance in bringing about a balance between Metropolitan and regional development and so, in reducing pressure on the Calcutta Metropolis.

(v) This will lay the basis for transforming this primate colonial metropolis whose economy still to-day is based on a colonial relationship with the countryside, into a centre for initiating and sustaining growth in the countryside. In this process the Calcutta Metropolis will be liberated from the necessity of depending on extracting food and agricultural raw materials for its industry and people on the basis of the existing property and institutional relations forcing the peasants to sell the food which they themselves need. Now the Calcutta Metropolis along with other urban areas, will supply the peasants essential industrial inputs (and consumer goods), which will increase agricultural production, and the peasants will give in exchange the surplus food and raw materials. Metropolis will thus get its requirement of food and raw material on the basis of affluence and not poverty of the peasants.

Massive investment in the CMD relief programme

This is the second most important

development under consideration. This topic will be dealt with in more detail elsewhere. Hence, rather than describing in detail the various schemes now being implemented, let us concentrate here on how it is contributing to the development of the new situation in the CMD and in West Bengal.

For the first time since independence, a sizeable fund was made available only in 1970 for the development of the Calcutta area. This has come at a time when the Calcutta situation reached a desperate level, from all points of view, and there appeared to be no hope for improving the situation in anyway. Significance of this massive investment can be understood only in this background of the all-pervading gloom and desperation. This investment sought to turn the tide, and usher in some hope in the horizon, hope that something positive may come up even in Calcutta area.

This investment has changed, so to say, the nature of the prevailing crisis in the CMD from one of stagnation and decay to one of growth and development. Just like stagnation, development also gives rise to host of difficulties and it is these latter difficulties that need be sorted out now. Whenever there is some real work, the question arises of coordinating the work, as well as of being sure whether these works are on the right track from the point of view of the development of the entire influence area of the CMD on the one hand, and its long term development need on the other.

Haldia Port and Industrial Complex

A few comments on the Haldia industrial complex may not be out of place here. It may be mentioned that while the new port will more than compensate the present decay of the Calcutta Port, the industrial complex for the area, so far committed, is deficient in two fundamental aspects. First, the mix of the industries planned may not be able to impart the required big growth impulse in productive employment generation in this region. The other aspect relates to the choice of technology. All the projects so far planned are highly capital intensive in nature.

The present capacity of the refinery is 2.5 million tonnes, and its entire Naptha will have to be piped to feed Durgapur fertiliser ; so nothing of it will be available for feeding the petro-chemical complex at Haldia. Both for meeting the demand in the region which is likely to be doubled in the next few years, and also to produce additional Naptha to feed a cracker of suitable economic size, immediate steps need be taken to at least double the eapacity of the refinery. However, setting up of the down stream units of the petro-chemical complex must not wait for doubling of the refinery capacity. It may be remembered that of the two major modern growth industries, viz. petro-chemicals and electronics, the Calcutta area has none, and for imparting a growth impulse to the stagnant industrial complex in Calcutta, it will have to be provided with a sizeable share of growth industries. For the time being these down stream units may be fed with imported raw materials which will be substituted by indigenous raw material from the cracker complex to be set up at Haldia when the necessary requirements of the raw material base, viz. Naptha is assured In view of the world shortage of Naptha and its relatively higher import cost, the alternative of importing cheaper Liquefied Natural Gas (LNG) as a feed stock for both fertiliser industry and petro-chemical complex may be considered. This gas may also be used in Steel Industry for saving on short supply metallurgical coal. Haldia is a very good location for setting up of terminal facilities for LNG. If this import of LNG, say from Indonesia, can be linked with a barter deal for exporting machinery and other manufactured products, it will have a double beneficial impact on the industrial economy of the area. In view of the reported possibilities, the feasibility of this project may be immediately gone into. Along with introducing a new growth element via the petro-chemicals in the Calcutta area industrial complex, immediate steps need be taken to develop a ship building and ship repairing industry at Haldia. The other complementary industries requird for ship building, as well as the natural advantage for setting it up are already there. This industry will also provide a big growth impulse to the existing engineering industry base of the area. One may also consider setting up of a sponge iron plant for Haldia. And there remains the question of electronic industry. The fantastic growth potential of this industry may be clear from the fact that the rate of increase in demand for electronic consumer products is about 10 per cent per annum in developed countries. The rate is similar for electronic medical equipment and it is far higher for computers etc. It may be further mentioned that in the year 1970 alone, Japan exported over 38 million radio receivers, and this quantity is more than twice the total quantity of radio receivers produced in our country. There is immense scope for this industry both for satisfying home demand as well as for exports. It has been estimated that relative cost of production of electronic equipment at Haldia will be 5 to 10 per cent lower than that in Europe. And if an electronic industrial complex can be developed in the proposed *Free Market Zone* in Haldia, the corresponding cost will be, it is reported, more than 30 per cent lower; and it will then be lower not only compared to Europe but also compared to Hong Kong. In connection with developing the Haldia industrial complex, one may have, therefore, to consider the question of a *Free Trade Zone.*

As regards the other aspect mentioned earlier, viz. the capital intensive nature of the proposed projects, it may be mentioned that even after opting for most advanced technology for producing the output, there often remains substantial scope to have some of the jobs done in the whole process through a labour intensive technique which while generating sufficient employment, does not affect adversely the quality of the final output. It appears that there is sufficient scope to go into the details of the specific mix of technologies in each project with a view to maximise employment without sacrificing the quality of the output.

Farakka Development

We wish to point out here that a large part of the benefit that was to accrue from Farakka may not really be available in practice due to the absence of an integrated plan for tapping the entire Ganga Basin. It is reported that already few schemes have been implemented, and some others are on the anvil, upstream in the basin which is likely to reduce by 50 per cent. the water that was originally planned for Farakka. Now we are hearing about the scheme for linking up the Ganga with the Cauvery which will divert further water from the former to the latter. The scheme is reportedly based on the fact that during the monsoon the problem in the Ganga is surplus water and that monsoon starts little later in the South. Therefore, it is said, that the Ganga-Cauvery linkage will transform the unnecessary surplus water of the Ganga with its potential danger of flooding into a boon. But the point to be investigated is that whether for supplying surplus water only for a few weeks such huge investment will be economic and also, once the investment is made, drawing water from the Ganga can be confined to few weeks only thereby jeopardising the required minimum flow downstream. If all these schemes are implemented the only benefit from Farakka may be reduced to the road-cum-rail bridge which could have been built with only a fraction of the cost that is being spent on Farakka.

It is not the purpose here to go into the merits of all the individual schemes relating to the Ganga basin. The point we wish to emphasise here is that the mere sum of some individually drawn schemes and projects does not necessarily constitute an overall efficient plan, and the total benefit that are likely to accrue from all these schemes is most likely to be far less, and the cost that are likely to be incurred on these individual schemes is likely to be far higher, than what it would have been under an integrated development plan for the whole basin.

Another aspect of this problem has arisen with the emergence of independent Bangla Desh as one of our most friendly neighbours. This has opened up the scope for tackling simultaneously the water management of the entire lower Ganga-Brahmaputra basin. Some study on this problem was reported to have been done by FAO, about a decade back. This study may be of some help to the Joint Indo-Bangladesh River Commission that has been already set up. This is likely to open up a tremendous development potential both for Eastern India and Bangladesh.

Emergence of Bangla Desh

It is not possible to grasp in this short time the immensity of the political, economic and social significance for India in general and West Bengal in particular of the emergence of Bangla Desh. The little that we have been able to realise so far indicates that its significance, at least so far as Eastern India is concerned, may be compared with that of gaining independence in 1947.

Our immediate concern here is the way it may be used for the revival of the Calcutta Metropolitan economy. It is clear to all that this may open up a vast market for Indian industry in general and Calcutta area industries in particular, and this may also solve one of the pressing problems of the CMD jute industry, viz. the problem of raw jute supply. This point may be dealt with in little more detail.

So far as India is concerned, we may conceive our primary role to be the supplier of those goods from which Bangla Desh has been deprived due to the severence of her ties with Pakistan. The immediate need for this, of course, can not be denied. But if we confine our role even mainly to the above aspect, the economic relationship between India and Bangla Desh can not become far different from what it was between the then West and the East Pakistan. In that case, Bangla Desh will remain—so far as India and other foreign countries are concerned—an exporter of cheap raw material like raw jute or unprocessed fish, and of the products of its agro-industry, jute industry which is not a growth industry, and an importer of industrial consumer goods. And as the ability to export such goods will be far less than the need to import the consumer goods, Bangla Desh will have to depend on foreign, including Indian aid and loan. And because their export base is not growth oriented, and their imports may mainly consist of consumer goods, the ability of Bangla Desh to eliminate the need for 'aid' or loan in the foreseeable future may not develop at all. This type of relationship will not only be harmful for Bangla Desh, but being most painfully aware what such relationship means because of their past association with Pakistan, she will certainly not like such a relationship. And it can be shown that, as had already been demonstrated in the case of Britain and recently in Pakistan, such a relationship will not be beneficial even to India in the long run.

It is with this understanding that the CMD economy will have to think the way by which it can not only get a market in Bangla Desh but can also supply such goods which may lead to a more self reliant growth of Bangla Desh, including her capacity to export more Such type of economic relationship, which will have to be partly based on 'aid' initially, will eventually eliminate all needs for aid, need for depending on another country.

Seen in this context, the relationship between India and Bangla Desh may be centered round the task of building a self-reliant economy in Bangla Desh, including building up an export base in growth sectors. CMD engineering industry can certainly play a crucial role in this venture.

Incentive Schemes for Industries

Considering the near-crisis situation in West Bengal industries, such incentives, most of which were already in operation in some other States, were considered by many as overdue in West Bengal. These incentives are expected to provide much desired relief to the West Bengal industries.

It will, however, be wrong to consider them as anything else but relief measures and need not be considered a substitute for even a sectorally conceived industrial development plan, or of a programme for a balanced regional development.

Neither the lack of raw material, nor the lack of market—which are the main problems of our industry not only in West Bengal but throughout the country —will be solved through these incentives. Reservation of market and of raw material for small sector, under these conditions, will directly mean curtailment of market and of raw material for the large sector. And this is the essence of any relief operation where we take away something from the rich to distribute it to the much needy poor. But this does not generate any new resource directly and as such this need not lead to development or growth.

Again, while the various fiscal incentives will be helpful to the small industries in backward areas, this will simultaneously lead to the curtailment of revenue for the State or State-sponsored organisation and hence curtailment of the capacity of the State to take action in some other field. Here also the similarity with relief measures may be noted.

The limitation of the above incentives becomes particularly clear when the industrial growth potential of the districts are proposed to be identified on the basis of 'local raw materials and skills.' This is an idea associated with the conception of agriculture and of rural area as merely a supplier of raw material and cheap labour, and has a very close affinity, although certainly unconscious, with the idea of the colonial masters towards their backward colonies. But the point to be grasped is that the agriculture and the rural areas (just like the traditional colonies) need not remain backward suppliers of raw material only, but must get transformed into a productive consumer of industrial inputs and services. In this scheme of affairs, agriculture is to be conceived also as a market for industrial inputs and services. Hence, in identifying the industries which can be set up in rural areas, due emphasis need be paid on the industries *required* to be set up for initiating and maintaining agricultural modernisation. The central task for industrial, and also for agricultural, development is to break the existing pattern of one way traffic between the two sectors, and so between the two basic spatial configurations, i.e. Metropolis and rural areas, and establish a two way traffic between them when each will supply its output for being used as input by the other.

The inability to go beyond relief measures in designing the incentive schemes is due to, amongst other, the inability to view simultaneously the problems of all the sectors—industry, agriculture, power, irrigation, transport, education, institutional reform etc.—in their mutual interrelationship sectorally as well as spatially for achieving some basic goals. And this brings us to the question of State Planning.

A State Development Plan

There now appears to be consensus that what now passes as State Plans are nothing but a collection of individual schemes stapled together and which are drawn without any conscious attempt to coordinate them for achieving some central targets of National and State economy. The only constraint those collection of schemes faced in their totality was that the sum of the expenditure proposed should not exceed the amount proposed by the Planning Commission. And from this way of formulating 'plans', it is but quite natural that the success of the individual schemes and hence of the plan as a whole, were measured by the amount of financial expenditure incurred. The more the expenditure, more successfull was supposed to be the plan implementation.

It is only in the above background that we may appreciate the immense positive significance of the reported decision to frame a real State Plan with some central targets. Its significance is further increased by the fact that for the first time in our history, West Bengal seems to have been able to draw some special attention from the Centre which will be crucial for implementing such a plan.

There being no scope in this paper to go into the details of the problems of State Plan formulation, we wish to conclude this section by pointing out what appears to be some crucial misconception in this regard.

It is being repeatedly mentioned by the political leadership of the country that the central emphasis in the coming plan should be 'distribution' in favour of the under privileged section of the people on the one hand and of more backward areas in the country on the other. There can not be any dispute with this central target, but one may certainly raise doubts regarding two of the implied assumptions of the. above directive. One is : though in the past *distribution* was not emphasised, production was emphasised. And the other is : now that distribution is being emphasised, it will not lead to the maximisation of production. That is, in other wards, in the past effciency was emphasised at the cost of equity and now this must be remedied by emphasising equity though it may mean a cost in terms of efficiency. Our contention is that both the implications are mostly wrong and are based on misunderstanding.

Even a cursory perusal of the levels of utilisation of the physical resources we developed during the past decades will convince any one that we could utilise even less than 50 per-cent of the potential that already existed. That is, the past plans resulted not only in inequity, but also in inefficiency. If we could have utilised nearly fully the already existing factories and other physical resources, not only production would have had significantly increased, it would have certainly led to a more liveable condition for the bottom 50 per cent of our people. And conversely, it is not necessary today to sacrifice efficiency and production for achieving equity and better distribution.

It is possible to demonstrate that the target of maximising production on the one hand, and of minimisation of interpersonal income differences and interregional developmental differences on the other, can be tackled in one frame, i.e. the above three targets can mostly be made mutually consistent. The whole of the State Plan need be built up to realise in practice the above possibility where equity can be made a tool for achieving efficiency and where maximum efficiency becomes a tool for achieving equity on the basis of a tolerable standard of living for all.

THE OTHER ASPECTS OF THE CMD SITUATION

We have described in the previous section the salient features of what is *NEW* in the present situation, *NEW* in the sense that these were not expected or foreseen in 1965-66 when the BDP, was prepared. In this section we shall concentrate upon describing the remaining other aspects of developments.

First, let us take population growth, BDP expected that the CMD population in 1971 would be 8.63 million with an upper and lower bound of 8 82 million and 8.48 million. Actual population for 1971, estimated at 8.2 million, is not only far below the expected level, it was substantially lower than the projected lower bound also.

Normally one should welcome such deviation from projections particularly when one of the most important causes of the present difficulties of the Metropolis is supposed to be high population pressure But, it is feared that less than expected population figure for the CMD, is an effect of the severe economic crisis in the CMD, which discouraged new inmigrants and encouraged those who lost their jobs particularly after 1965 to leave CMD and go back to their village homes. It may be remembered that in the Registered Factory sector alone, employment went down by 97 thousand in the four CMD area districts between 1965 to 1969. If we could take into account non-registered industrial units and the units in the service sector, the above figure of employment loss would certainly become much bigger. Thus, less than expected (or feared) population growth, most probably due to an unexpected recession, is the first fact to be reckoned with. It may also be noted that taking the State as a whole, the level of urbanisation has remained static at the level of 24.6 per cent. Another demographic aspect relating to West Bengal occupational structure may be mentioned here. Compared to a population increase by 9.5 million (or by 27.24 per cent), working force has increased by only 1 million (or by less than 9 per cent). And the proportion of working force to total population has decreased from 33.2 per cent in 1961 to 28.37 per cent in 1971, only a part of this decline can be explained by changes in definition. And among the agricultural population, the proportion of landless workers has increased from 28 per cent in 1961 to more than 44 per cent in 1971.

Despite the recession, the position of power supply has reached a state where it can not ensure power even to our semi-stagnant industries. If we start rural electrification in a big way leading to universal modernisation of agriculture and based on it a viable growth of dispersed industrial and servicing centres, we may need on an average, 65 MW per additional thousand villages. Taking the total need for rejuvenated industry, modernised agriculture, as well as that for household *additional* power generation required will certainly be not lower than 400 MW per year for the coming 15-20 years. Against this need, actual installed capacity has increased from 1498 MW in 1966-67 to 1528 MW in 1969-70 i.e. at a rate of only 10 MW per year !

Another important bottleneck has become the lack of wagons. It may be remembered that it was the lack of order for manufacturing wagons that initiated the recession in engineering industry in West Bengal. Thus, the number of wagons built in West Bengal went down from 20,758 in 1964-65 to only 8,585 in 1967-68. During the same period, the total for India as a whole decreased from 34,543 to 17,633. And now, the lack of wagons is one of the root causes for the critical shortage of essential inputs in the different areas jeopardising the entire time table, and also the cost estimates, of different project implementation programmes.

The problem of idle capacity in our capital scarce country has been discussed by us exhaustively in several of our documents. This problem, to which we first drew attention in 1965 and again in 1967, has in no way become less serious now than what it was 3-5 years back. It has been estimated by the Reserve Bank of India that even on an all India level, production could have been increased by at least 77 per cent in 1967 by just fuller utilisation of existing capacity. That the problem is certainly more serious in West Bengal is well known. It need be emphasised that the removal of bottlenecks to fuller capacity utilisation—whether it is technological, institutional, or having roots in faulty government policy—should constitute one of the basic planks of the State Economic Development plan. And, so far as Metropolitan Plan is concerned, it should constitute the central focus.

AN ECONOMIC DEVELOPMENT PROGRAMME FOR THE CMD

The Basic Strategy

The basic strategy should centre round the following four facets of industrial development :

(a) utilising existing capacity
(b) creating new capacity
(c) specifying the appropriate location, and
(d) developing the required infrastructure

For utilising the existing capacity, we must have a fairly accurate detailed quantitative estimate regarding itemwise existing capacity and the constraints to its full utilisation. One important contraint will be lack of inputs. It will be an important aspect of industrial development to try to develop new capacities for supplying such inputs. Another aspect of the same process will be diversifying some of the existing capacities or creating new ones for serving the requirements of rapid agricultural modernisation which will be the kingpin in the present decade for the total revival of our economy.

Apart from the new capacities mentioned above, immediate steps will have to be taken to implant, what are called, growth industries in the Calcutta area. Despite the fact that the Calcutta area is, and will remain so at least for coming few decades, one of the biggest concentrations of market in our country, the new industries which are ushering in a new industrial revolution in the world, viz. electronics and petro-chemical are yet to be developed in the Calcutta area. Calcutta was the pioneer in the chemical industry in the old days. But these were the old type chemical industries depending on old type of raw materials. And it is, therefore, no wonder that the chemical industry in Calcutta is relatively stagnating while the same, say, in Maharastra and Gujarat is thriving because these are new types of chemical industry. Calcutta can revitalise her industrial economic base by injecting a big dose of these new growth industries.

So far as the problem of locating the new growth industries in the metropolitan area are concerned, it may be said that those which will cater to the home demand should locate themselves in or near the market centres such as CMD. But the units which will be export oriented can best be located in Haldia

For choosing appropriate locations within the CMD area, there should be planning attempt to *concentrate new development* in a new growth centre This is required, amongst other reasons, to utilise the economy of scale in providing infrastructure as well, as to avoid the diseconomics of scale as it is now operating in the Metropolitan core in the Calcutta and Howrah cities and their immediate suburbs due to over concentration. In the latter areas it is relatively more costly to provide the infrastructure. And in a new growth centre, if there is not sufficient concentration, it may mean that even the minimum infrastructure of road, water supply, drainage etc. will only be partly utilised making the costs per capita unnecessarily high. An example at hand is Kalyani Development.

As suggested in the BDP a serious attempt will have to be made to develop a really big growth centre at the northern tip of the CMD, viz. in the Bansberia-Kalyani area. The advantage of, and the necessity for, developing such a centre have been dealt with elsewhere adequately. We merely want to emphasise here that the policy of new industries in that centre will be a positive tool for developing this new centre of growth.

So far as locating new industries in the backward, rural areas of the country is concerned, it will have to base itself on industrialising, and modernising agriculture. Neither the provision of physical infrastructure as such for the development of some outlying towns as 'growth centres' or some fiscal incentives to locate some industries in outlying areas can be successful tools for developing backward areas, particularly with socio-economic justice. The infrastructure as well as the towns and cities serve basically the existing dominant socio-economic forces. The railways in colonial India did not develop India. Nor did the Calcutta city or the Calcutta Port help developing her hinterland in the nationally desirable direction. The only force they helped developing is that of speculative commerce, absentee landlords and similar other socio-economic classes. Even today the role of the Calcutta city in its hinterland has not basically changed.

It is only in this context that one may understand the importance of, and the necessity for, a rapid technological modernisation of our agriculture (i.e. most of our 'backward areas') on the basis of equally rapid socio-economic modernisation of the institutional structure by providing land to the actual tillers through abolishing concentration of land ownership along with its appendages in the form of rack renting, usury and speculative commerce. Such a modernised rural area and agriculture only can utilise for there own benefit the existence of physical infrastructure and of the cities and other growth centres. And in addition, they will require new industrial and servicing units, and new centres for providing their needs. It is on the basis of their requirements that the rural area will become appropriate locations for new industries. It is only such a development of our countryside—which encompasses almost the whole of our land and the overwhelming majority of our people—that can, so to say, liberate Calcutta from its disgusting colonial heritage and enable it to play its due role of a metropolis in a resurgent country. The strategy of Metropolitan Planning will have to be reviewed and redesigned with the above overall developmental objective of our state and the nation as a whole.

THE AREA PLANNING APPROACH FOR AGRICULTURAL DEVELOPMENT IN THE HOOGHLY BASIN

S. B MUKHERJEE

Abstract

Uptil now our approach has been the so-called sectoral approach in planning. Little attention has been paid to spatial approach or the geometry of planning. Area planning has been a long established concept in the urban sphere. We should extend the concept of area planning from urban areas to rural areas. The goals and objectives of area planning are to be derived from national goals and objectives. And in area planning the district provides the most suitable level of planning, though it may be divided into sub-areas as the lowest level planning units.

Administrative difficulties for planning at lower than district level will be prohibitive. Moreover, a district has been the most effective and well-established administrative unit of India. Popular enthusiasm can be most effectively roused if plans are made area-wise rather than state-wise. The paper deals with the benefits out of such an area development plan. It also outlines an approach for formulation. of district development plans.

Planning in India has no doubt had some impressive achievements but it has suffered from some serious failures and setbacks. Planning has failed to rouse the enthusiasm of the people, and the benefits of development have failed to reach the grass roots. Many factors might have been responsible for this. But one of the most important factors lies in the technique of planning. Uptill now, our approach has been the so-called sectoral approach. Planners have considered the different sectors of our economy, e.g. industry, agriculture, trade, transport etc. They have also divided each sector into so many sub-sectors and have taken decisions of investment in the different sectors and sub-sectors of the economy. Unfortunately, uptill now, little attention has been paid to a new dimension of planning i e. space. We have made detailed calculations of how much steel is to be produced, how much investment should be made in fabricating industry, how many barrages are to be constructed and how many miles of canals have to be dug. But we have seldom concerned ourselves with the problem—what is the most important need of a particular area (say a district) or how the area can be developed economically, socially and culturally in the shortest possible time. In short, planners in India have been too much concerned with the so-called arithmetic of planning and too little concerned with the so-called geometry of planning.

A new approach has been suggested in the field of planning and development ; an approach towards area planning in rural areas generally and in agriculture particularly. Area planning has been a long established concept in the sphere of urban planning. Urban planners are used to take a small area within a city (may be a blighted area or a new town) and prepare physical designs for its all round development. It is true that urban area planners take into consideration the various social, economic and cultural factors and formulate their physical planning schemes on the basis of some overall objectives to be achieved for the city as a whole and the specific role of the particular area in contributing towards the attainment of these overall objectives. In our present context we extend the concept of area planning from physical planning to economic planning and development planning and also from urban areas to rural areas.

AREA PLANNING

What is the nature of area planning in this context ? We can understand the nature of area planning by contrasting it with national planning. For planning at the national level, we have to have some goals and objectives, some policies, some targets and some tools to achieve the targets. In respect of area planning we do not have an independent goal or an independent policy. Rather, the goals and objectives of area planning are to be derived from national goals and objectives. Also the policies pursued and the tools applied in area planning must be consistent with the policies and tools adopted at the national level.

The case for Bhagirathi-Hooghly Basin

Why does the need for area planning arise at all ? The need arises because the conditions of different regions, sub-regions and micro-regions within the nation as also within a State vary greatly in respect of their physical features, their natural endowments, their economic prospects, their development potential, the social habits, needs and aspirations of the people. That this awareness is already there in the minds of our intellectuals is apparent from the fact that in this Seminar we are discussing a special topic entitled problems of planning in the Bhagirathi-Hooghly basin. If problems of planning were independent of the conditions in the different regions in India, there would have been no need to discuss such problems in respect of the Bhagirathi-Hooghly basin. An abstract plan document for India as a whole would provide direct and immediate guidance to the making of investment decisions for all the regions and micro-regions in the country. It is because the physico-geographic conditions and socio-economic features of each particular region have an important bearing on the type of planning most suitable for the region, that we are at all discussing the problem of the Bhagirathi-Hooghly basin. Our point is that the Bhagirathi-Hooghly basin itself is too big a region and also too heterogeneous a region to prepare effective area development plans. The texture and properties of the soil, the conditions of the river, and the availability of water in the western fringe of Midnapore district or in the Purulia district radically differ from those in the districts of Burdwan or Hooghly. Similarly relief and contour, soil composition and rainfall and the most suitable cropping pattern in the Asansol sub-division of Burdwan district markedly differ from those in the riparian villages on the Hooghly bank. We would, therefore, tend to think that the district provides the most suitable level of planning, though a district is to be divided into so many sub-areas as the lowest planning unit.

Of course, conditions differ even within a district but administrative difficulties for planning at any lower level would be prohibitive. A district has been the most effective and well-established administrative unit in India for the last 150 years and all branches of administration are unified in one single office in the district. Availability of data and unification of control make it necessary that we make a compromise between the needs of homogeneity and the needs of administrative efficiency and restrict ourselves to planning at the district level—at least for the present.

Benefits of Area Planning

The benefits out of such an area development plan may be briefly summarised as follows :

(1) As wide disparities occur between the physical and environmental conditions of different areas, it is through planning at the area level that proper care can be taken of the specific conditions in each area. By planning at the State level or National level, one cannot expect to utilise the full potential of each specific area or to most economically use the natural endowment in such an area.

(2) Not only the natural endowment but also man-made infrastructural facilities differ widely as between one area and another. The purpose of any planning effort should be to utilise to the best possible extent whatever infrastructures are already available before making investments to build up new infrastructures needed for the development of the area. Planning at the area level makes it possible to put the existing infrastructures to better use than planning at the State or higher levels.

(3) Needs and aspirations of the people also differ widely as between different areas. For instance, the needs of the rural populations in the district of Purulia very much differ from the needs of the rural populations in the district of Burdwan. In one area employment may be the most crying need, in another area food may be the most urgently needed end-product. In still another area cash may be the most craved for object. Planning at a State level fails to take proper account of all these diverse needs. It is planning at the area level which could be made to fit into the specific needs of each area.

(4) A corrollary from the above is that popular enthusiasm can be most effectively roused and popular co-operation

can be best enlisted if plans are made area-wise rather than State-wise. By now all people are convinced that without popular co-operation and popular contribution, a development plan cannot be successfully implemented. This turns the scales decisively in favour of area planning.

(5) Mobilisation of local resources for local planning may be much easier than the mobilisation of the needed resources for national development plan. To illustrate from the Bhagirathi-Hooghly Basin again, it would be easier to raise money for a river lift irrigation scheme in Arambagh or Khanakul Blocks in Hooghly district or a link channel system from the net-work of Damodar Canals in the Memari Block of Burdwan district from the people in the respective areas in which such schemes are located than to raise money for irrigation in West Bengal from the people of West Bengal generally.

(6) Finally, after the completion and implementation of a plan an evaluation of the plan may be done in a more sure and in a more direct way from the benefits accruing to the community of that area than if such evaluation were attempted for State level or National level plans —the benefits of which would be too much scattered and much more diffused in a wide area, and among a large number of people.

FUNCTION OF STATE PLAN

Is it then suggested that there will be no national plan or no State plan ? Our intention is far from that. The need for a National plan or a State plan not only does not diminish but really increases as a result of the area planning approach. The point is that the function of the State plan will be to co-ordinate and integrate the numerous area-development plans, which will be used as inputs in the formulation of the State plan or national plan. For instance, after the district development plans for each of the districts in the Hooghly Basin have been prepared, such plans will have to be integrated into a plan for the development of the Bhagirathi-Hooghly Basin. This, in its turn will have to be co-ordinated with the plans for other geographic regions of West Bengal—to lead finally to the formulation of the State Plan for West Bengal. In the process of such integration a considerable amount of pruning, adjustment, modification and expansion in the individual area development plan will be necessary —the constraints of resources being there. And, it may be easier to determine the priorities of different schemes on the basis of the intimate knowledge of the areas and a close understanding of the benefits expected out of the different schemes. We may go a little further and suggest that an examination of sectoral consistency of the planned investments and a judgement of the efficacy of the various schemes in respect of the realisation of the national objectives may be better done through the area planning approach.

It is not difficult to appreciate that side by side with area level schemes there will be many State level schemes and National level schemes. The setting up of a Steel Plant, for instance, in the Hooghly Basin cannot but be planned except at the National level. The decision to take up an irrigation scheme like Kangsabati Project or a Mayurakshi Project or a Fertilizer Project have got to be taken at the State level. Such National level projects or State level projects may be actually located in a particular district within the Hooghly Basin. But the benefits flowing from such projects are enjoyed far beyond the boundary of such districts and the location of such projects cannot be done efficiently on considerations of factors limited to a particular district. However, though such projects are decided upon at the State level or National level, the purpose of area development plans should be to create suitable infrastructure locally, so that maximum benefits out of these State level and National level projects flow to the respective areas. In other words these higher level projects should be taken as exogenously given to the area and the indigeneous plans of the areas should be fitted into the frame of these.

FORMULATION OF DISTRICT PLAN

A method of approach for formulation of a district development plan may be somewhat like this. First, some objectives to be achieved through the district development plan must be set up (which will not only be -consistent with the national objectives but also should positively contribute towards achieving the national objectives in the quickest possible time). Secondly, the district should be divided into so many economic activity areas. The third step should be the collection of data on the various aspects in the rural economy in the district—such as natural resources, land utilisation, agricultural activity, flow of goods, social facilities etc. The fourth step is to put all these data on maps, examine and analyse them, study the achievements and failures in the field of agriculture, make a judgement of the prospects and possibilities in respect of the development in the agricultural and -other sectors and make suitable recommendations regarding the cropping pattern to be achieved. The final step would be to suggest the investment implications of such recommendations in terms of agricultural inputs, infrastructure, and social facilities to be created.

AN APPROACH TO THE LOCATION OF FUTURE URBAN CENTRES (GROWTH POINTS) IN THE HOOGHLY-BHAGIRATHI.

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Abstract

The Hooghly-Bhagirathi Basin which contain the strong urban industrial core around Calcutta has a vast tract of agrarian land with occasional dots of urban places excepting a few recently developed centres.

This sort of development does not favour trickle down effect of growth impulses and economic advances from higher order centres to smaller places. Simultaneously, this has caused not only the resistances to the diffusion process of high productivity and quality products into the agrarian land but also have made the hierarchical system of agricultural marketing backward. A combined effect has lowered down the regional economic growth which is a competitive game in both marketing and planned economies. Growth can be traced back to individual location decisions though the space economy is a series of interdependent network over which many individual functions like diffusion of urban facilities, operation of market forces, distribution of agricultural uses etc. act.

In this paper attempt has been made through varied types of model studies to find out the probable types of hierarchical framework of centres diffusing central place functions for which goods to be handled, services to be diffused, transactions to be made would aim at a rational system.

Regional growth can be traced back to individual location decisions though the space economy is a series of overlapping, interdependent networks over which many individual production and marketing forces act. When a set of activities of different kinds is distributed over the plain containing the network the urban hierarchy will result. In this hierarchical framework there will be centres of different levels of strength for which goods to be handled and transactions to be made will be of different patterns.

Regional growth theories suggest that continued urban-industrial expansion in major central cities should lead to catalytic impacts on surrounding regions. Growth impulses and economic advancement should "trickle down" to smaller places and ultimately infuse dynamism into even the most tradition-bound peripheries. But this has not occured in India (Berry, 1967). In the Hooghly-Bhagirathi Basin cities and towns (which are known as central places in classical theories) are neither well distributed nor have got nodal point location due to occurrences of many physical constraints like water lines, international boundaries, gradients, soil conditions, danger of floods and negligence towards extensions of communication lines. Moreover, concentration of earlier industrial activities with later tertiaries did not find much favourable factors for their locations at many places, particularly away from transportation lines.

The market towns are not only envisaged to create a package of local opportunities but also to cater the agricultural needs of the region i e. distribution of agricultural inputs, serving deficit areas with deficient goods and over and above everything else trading the surplus goods to higher order urban centres and deficit areas. By achieving a proper distribution of such market towns we will arrive at an urbanisation plan befitting the agricultural economy of the region. From these hierarchies of market centres planners would be able to easily reach at decisions concerning priorities in plan.

In any study area for administrative conveniences the optimum nesting order of urban fields is by sevens (K=7), (Christaller, 1957). Similarly for free entry competitive optimum urban hierarchy is one in which, where the triangular geometry obtains, urban fields nest by a rule of threes (K=3). Where the constraints of an inter-city transport network apply and the lower level centres are required to adjust their locations, urban fields appear to nest by a rule of fours (K=4). In every case on a uniform plain the basic geometry is a hierarchical hexagon.

Though an attempt has been made to fit all the above mentioned systems in the Hooghly-Bhagirathi Basin the available pattern of homogeneity has put severe constraints on the overall urbanisation, (which is varying over a great range) the number of postulated lower level centres (which being too many in some cases cannot be found in reality) and above all a rare occurrence of hexagonal framework. Hence, besides these three classical approaches of Christaller's rules in this paper another approach is tried making a compromise between the classical concepts of a set of many other factors which should be considered if a befitting framework has to be arrived at for this peculiar region. However, the ultimate study is to suggest possible policies and strategies that will break through the polarity of highest order metropolitan centres and the village. In many cases metropolitan centres do not prove themselves fitted in the system with their fast changing economic activities some of which are highly specialised. They render services to very vast areas over the nation and sometimes over many nations' tracts.

The Bhagirathi-Hooghly Basin covers the entire catchment area of the Bhagirathi-Hooghly and their tributaries, and extends over 11 districts of West Bengal (Murshidabad, Nadia, Birbhum, Burdwan, 24-Parganas, Calcutta, Howrah, Hooghly, Midnapur, Bankura and Purulia) and 4 districts of Bihar (Santal-Parganas, Hazaribagh, Dhanbad and Ranchi). Observations and constraints for central place functions in the Hooghly-Bhagirathi Basin area are as in the next column.

GENERAL

Total area—	46,407.2 square miles.
Number of villages—	52,748
Number of urban centres—	205
Average population of villages—	566
Density of population—	Total 767/sq. mile Rural 645/sq. mile
Number of Thanas—	373
Average village size—	0.879 square mile.

POPULATION

	Existing—1961	Projected—1981
Rural—	26,517,792	40,385,000
Urban—	8,877,818	16,953,000
Total—	35,395,610	57,338,000

TABLE—1

Existing Administrative cum trading Centres—Number and population (1961)

Centre	Numbers	Average central place population	Rural Population served
1. Metropolitan	1	2,927,289	26,517,792
2. District	14	99,468	1,990,526
3. Subdivision	33	30,793	622,039
4. Block head-quarters	325	11,589	80,047
5. Hats/Rural grain markets	2,145	N.A.	N.A.
6. Villages	52,748	N.A.	N.A,

Source : Census of India—1961.

TABLE—2

Existing urban centres by order of concentration

Centre	Numbers	Population Range
1. Metropolitan	1	2,927,289 (actual)
2. Cities (Class I)	13	100,000 +
3. Towns (Class II)	20	50,000 — 100,000
4. Towns (Class III)	66	20,000 — 50,000
5. Other urban centres (Class V & VI)	105	< 20,000

Source : Census of India, 1961.

In order to get the essential constants that would help deriving central place population in relation to rural population served it is necessary to consider some sort of centre-ranks prevailing in the region. In the absence of clearcut rank-size distribution in urban places or any order in marketing functions the only way to have some sort of functional levels is to search in the existing system of administration. Such systems are as follows :

1st system	2nd system	3rd system
1. State	1. State	1. State
2. Division	2. Division	2. Division
3. District	3. District	3. District
4. Sub-Division	4. Sub-Division	4. Sub-Division
5. Block	5. Thana	5. Tehsil
6. Gram Panchayat	6. Union Board	6. Block Panchayat
7. Village	7. Village	7. Village

The general formula characterising urban hierarchy in a Christaller's system which bears an exponential relationship is given by

$$\log C = K + q \log R \qquad \dots (1)$$

where

C=central place population

R=Rural population in urban field

q, K are Constants.

ADMINISTRATIVE PRINCIPLE

In order to fit best the conditions of administrative principle of central place functions the number, average central place population and average rural population served given in Table-2, would provide the actual relationship as

$$\log C_a = 0.390 + 0.744 \log R_a \qquad \dots (2)$$

Obtaining the projected rural population of 40,385,000 within the total area of 46,407.2 square miles and following the administrative principle (K=7),(Fig-1) the 1981 pattern of central place hierarchy would be as presented in the Table-3.

(i) The first order single Metropolitan Centre showing an average central place population of a little over one million may not be justified in the background of its present status with population approaching 3 million mark. The excess population over the population that has come out of this system of the model could be explained only when this centre is accepted as a first order centre of a still larger region or the nation itself. Before 1965, it was extending services and goods to people beyond international boundaries in Pakistan, Nepal etc. The truncation of the Bengal Plain has affected to a great extent the economic processes and circumstances of this spatial organ.

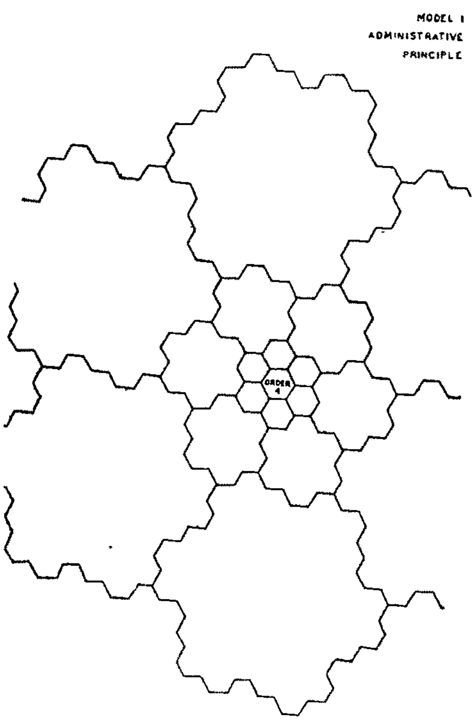

Fig. 1

TABLE—3

Expected Characteristics in the five-tier Administrative principle Model I (1981)

Centre	Number	Cumulative No.	Average central place population	Average rural population
1st Order	1	1	1,122,000	40,385,000
2nd Order	6	7	298,500	6,730,833
3rd Order	42	49	70,790	961,547
4th Order	294	343	16,220	137,364
5th Order	2,058	2,401	3,890	19,623

(ii) The six second order centres with an average central place population nearly 3 lakhs each, again depict some discrepancies in the status of the existing 14 district centres with an average approximate population of 1 lakh. At present none of the 12 class-I towns excepting Howrah has crossed 3 lakh mark though a few others promise to fill the deficiency with tremendous growth that could better be explained by strong industrial economic base. Even some class-II towns like Durgapur etc. assure with their still higher growth potentials to meet the deficiency in this respect.

(iii) The third order 42 centres with an average central place population of over 70,000 seem quite justified when compared with the existing 33 subdivision centres with average population of over 30,000 particularly when one looks toward the existing 32 urban places of class-I and II combined. The expected high industrial, commercial and other tertiary growth of the Hooghly-Bhagirathi Basin would certainly help flourishing such centres.

(iv) On the contrary the average fourth order central place population of 16,000 for 294 centres is relatively high when compared with the existing average approximate central place population of 12,000 for 325 Block headquarters. It is expected that there will be no dearth of centres in this order because of the expected enhanced activity of the Block head-quarters as market places for manifold agricultural outputs, distribution centres for agricultural inputs and seats of decentralised administrative activities through Block headquarters.

(v) There will not be any crisis for expected 2,058 hats/wholesale grain centres in the fifth order, in view of the existing 2,145 hats.

(vi) Area served, travel distance from farthest point and distance between two central places of adjacent fields of the same order are as in Table-4.

TABLE—4

Comparative Distance Components

Centre	Area served (A) (Sq. miles)	Farthest point served (a) (in miles)	Distance of the nearest central place of same order (d) (in miles)
1st Order	46,407.2	133.9	205.45
2nd Order	6,915.4	51.6	89.4
3rd Order	987.9	19.3	33.2
4th Order	141.1	7.4	12.8
5th Order	20.1	2.79	4.8
6th Order	2.87	1.05	1.82

MARKETING PRINCIPLE

The existing conditions give the exponential relationship between central place population and the corresponding rural population served in a marketing hierarchy (K=3) as

$$\log C_m = -2.894 + 1.227 \log R_m \quad \cdots (3)$$

With the help of the projected rural population of the region as 40,385,000 within its boundaries a hierarchical pattern of central place function would be developed based on marketing principle. (Fig-2)

(i) In this framework the only one first order Metropolitan centre shows a population of 2.7 million which is less than the existing order of approximate 3 millions. There is every possibility that since there are least chances of depopulation and deconcentration the Metropolitan centre may have a population much more than 3 million by 1981. This excess population over the expected 2.7 million could be justified only by the phenomenon that this first order centre will be playing the role of a first order centre of a still larger region say, Eastern India Region or Four State Region.

(ii) The assessed population of 7 lakh each for 3 second order centres may not be justified in view of the present populations of District centres and class-I cities. Only

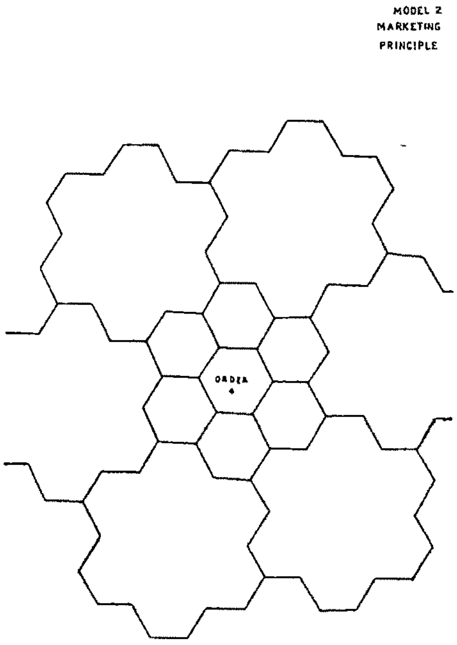

Fig. 2

TABLE—5

Expected characteristics in five-tier marketing principle Model-II (1981)

Centre	No.	Cumulative No.	Average Rural central place population	Average Rural population served
1st Order	1	1	2,667,000	40,385,000
2nd Order	3	4	709,600	13,461,666
3rd Order	12	16	130,600	3,365,416
4th Order	48	64	28,250	841,354
5th Order	192	256	4,406	210,338

possibility rests on the factors of tremendous industrial and tertiary growth of topmost 3 class-I cities (other than Calcutta) like Howrah, Asansol etc.

(iii) The 12 third order centres with population of 1.3 lakh will be represented mostly by District centres with population more than 1 lakh and class-I cities. In some cases emerging urban centres with strong industrial base will help meeting the crisis.

(iv) The fourth order 48 centres of 28,000 population are expected to come out mostly from subdivision centres and class-II towns.

(v) The fifth order centres would be 192 in number which require a competitive selection out of 325 existing Block Headquarters class-III towns with higher growth potential and hats with larger volumes of wholesale.

(vi) Area served travel distance from farthest point and distance between two central places of the same order are as in Table-6.

TRANSPORTATION PRINCIPLE

In the area under study following trade-route hierarchy of central places the existing conditions give exponential relationship between central place population and the corresponding rural population served as

$$\log C_t = -2\ 689 + 1.200 \log R_t \quad \ldots \quad (4)$$

TABLE—6

Comparative distance components

Centre	Area served (A) (in Sq. miles)	Farthest point served (a) (in miles)	Distance of the nearest central place of same Order (d) (in miles)
1st Order	46,407.2	133.9	205.45
2nd Order	11,601.8	66.9	115.9
3rd Order	2,900.5	33.4	57.7
4th Order	725.1	16.7	28.9
5th Order	181.3	8.3	14.4
6th Order	45.3	4.2	7.25

The projected rural population of 40,385,000 of the Basin would help calculating the central place population and their numbers with average population served by each as shown (Fig-3) in table-7.

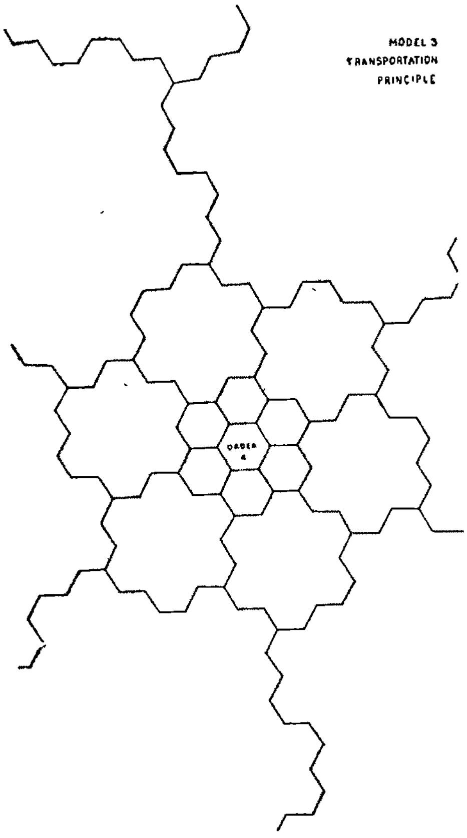

Fig. 3

(i) The expected population of the single 1st order centre would be 2.6 million by 1981 which is much less than the existing 2.9 million of the same. Its popuiation may be much more than 3 million by 1981 which could be explained by its role as a central place of transportation principle for a much larger region than the Bhagirathi-Hooghly Basin.

(ii) The 2nd order centres which would be 4 in number with population a little over 5 lakh each could be sought out from the existing Class-I cities with highest population and fastest growth rate of urban economy.

(iii) The 3rd order centres would be essentially the selected district centres and class-I cities. Their average population will be 73,000 which is again lower than the existing average of district centres.

(iv) The 100 4th order centres with

TABLE—7

Expected characteristics in five-tier Transportation Principle Model-III (1981)

Centre	No.	Cumulative No.	Average central place population	Average Rural population served
1st Order	1	1	2,636,000	40,385,000
2nd Order	4	5	514,000	10,096,250
3rd Order	20	25	72,610	2,019,250
4th Order	100	125	10,620	403,850
5th Order	500	625	1,535	80,770

11,000 population for each are to be selected from 33 subdivision centres and 325 Block Headquarters

(v) The 500 5th order centres with average population of 1,535 are essentially the Block Headquarters and hats of significant transactions.

(vi) The overall framework shows that both 3rd and 4th order centres are not good fits because of their low central place population assessed. On the other hand the 2nd and 5th order centres are undoubtedly good fits.

(vii) Area served, travel ditance from farthest point and distance between two central places of the same order are as in Table-8.

COMPOSITE MODEL IV

For the Bhagirathi-Hooghly Basin, when none of the above models were found much suitable a composite type of model (Fig-4) is attempted with some compromising principles. Such compromise may be among :

(a) Existing centres—their locations and levels ;

(b) Any one or more of the classical principles ;

(c) Maximum coverage by its centre—if a certain order is to diffuse maximum central place functions to space ;

(d) Minimum overlapping of tributary areas to the central places of same order ;

TABLE—8

Comparative Distance Components

Centre	Area served (A) (sq. miles)	Farthest point served (a) (in miles)	Distance of the nearest central place of same order (d) (in miles)
1st Order	46,407.2	133.9	205.45
2nd Order	9,281.4	61.6	106.8
3rd Order	1,856.3	26.6	46.1
4th Order	371.3	12.0	20.8
5th Order	74.3	5.3	9.18
6th Order	14.9	2.4	4.1

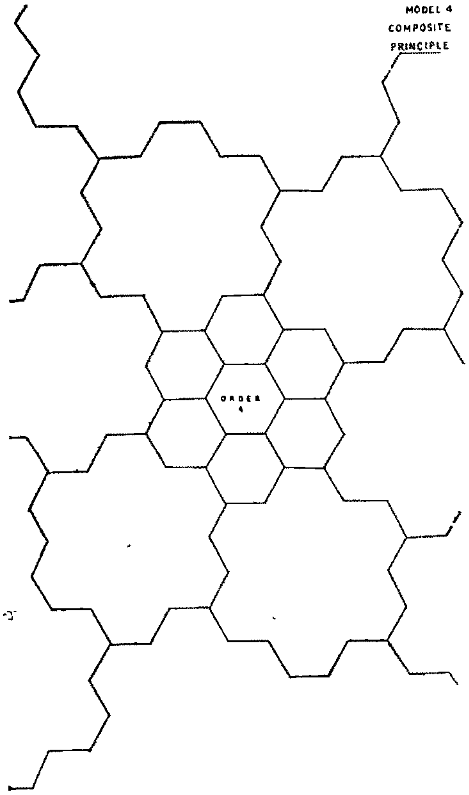

Fig. 4

(e) Less importance to less developed areas but not ignoring ;

(f) Specific choice for specific centres ;

(g) Much importance is to be given to the marketable surplus of deficit at Block levels or even for tributary areas to hats because the surplus/deficit is a factor of both productivity and consumption. This criteria must be of different levels according to the order of central place and hence a due consideration is attributed towards the scale economy of marketing ; and

(h) Geographical distance.

The projected rural population, 40,385,000 for 1981 and place to place examination by using the compromising terms as tools would provide a certain type of hierarchical pattern which is though not regular in hierarchy still has much importance in ordered urbanisation and diffusion of functons in the Basin.

(i) It gives a system of 5 second order centres of population range 200,000 to 500,000 which has easily escaped the error found in other cases where exact central place averages are provided. Most of these centres are searched from the existing cities though coverage also plays a great role.

(ii) Similarly, 18 third order centres give a range of 50,000—150,000 which again can escape such criticisms. About half of these 18 centres are District head-quarters and the rest are cities, sub-division centres or places of excessive industrial concentration. They follow in their best ways the compromising terms already referred.

(iii) 56 fourth order centres will have 20,000-50,000 range of population, and most of them are sub-division centres screened Block Head-quarters or industrial centres selected on the basis of compromising terms.

(iv) On the whole the overall frame-work provides a good coverage particularly because of the logical choice of centres some of which are though remote in situation, have good amount of wholesale transactions.

(v) Overlapping was tried to be avoided but at many places even over 50 per cent are accepted.

(vi) Areal division of the 1st order catchment into 4 IInd order and

TABLE—9

Five-tier Composite Model IV—(1981)

Centre	No.	Central place* population Range	Average Rural Population served
1st Order	1	3,000,000— 4,000,000	40,385,000
2nd Order	5	200,000— 500,000	10,096,250
3rd Order	18	50,000— 150,000	2,524,062
4th Order	56	20,000— 50,000	631,015
5th Order	Not examined	5,000— 20,000	N.A.

* Based on Projections for individual centres.

consequently the second order catchment into 4 3rd order and so on, has derived a tactful technique to bring marketing hierarchy into consideration.

(vii) Some of the fifth order centres which will have populations within the range 5,000-20,000 may be treated as urban places depending on their levels and types of activities.

(viii) Area served, travel distance from farthest point and distance between two central places of same order are as in Table-10

(ix) Criterias for Selecting Centres (Model IV) by Screening Method :

(A) The centres are selected with the score points they secure. Scores are given on the basis of facilities available at the location and higher the aggregate score, higher is the position in the screening table.

(B) Scoring points are arranged according to priorities as follows :

(1) District H. Q., (2) Sub-Division Centre, (3) City Centre,

TABLE—10

Comparative Distance Components

Centre	Area served (A) (Sq. miles)	Farthest point served (a) (Sq. miles)	Distance of the nearest central place of same order (d) (Sq. miles)
1st Order	46,407.2	133.9	205.4
2nd Order	7,734.5	54.6	94.6
3rd Order	2,442.5	30.7	53.1
4th Order	814.2	17.8	30.8
5th Order	Not examined		

(4) Town Centre and census size class, (5) Wholesale grain market, (6) Zonal market, (7) Railway Junction/Station/track passing, (8) National Highway/State Highway/District Roads, (9) Nodal points, (10) Rural extension facilities and (11) Services etc.

Following the above method the centres for the Bhagirathi-Hooghly Basin are arranged as follows :

Centre Order	No. of Centres		Name of Centres
1st Order	1	—	Calcutta.
2nd Order	5	—	Howrah, Kharagpur, Ranchi, Asansol, Berhampore.
3rd Order	18	—	Burdwan, Bally, Durgapur, Dhanbad, Bhatpara, South Subarban, Serampore, Bankura, Purulia, Krishnagar, Barasat, Midnapore, Dum Dum, Hazaribagh, Murshidabad, Deoghar, Suri, Haldia.
4th Order	56	—	Dumka, Madhupur, Giridih, Jharia, Muri, Ramgarh, Adra, Bishnupur, Contai, Raghunathpur, Kalna, Katwa, Bolepur, Ranaghat, Kalyani, Nabadwip, Barrackpore, Basirhat, Diamond Harbour, Baruipur, Canning, Garden Reach, Sankrail, Uluberia, Konnagar, Kakdwip, Chandernagar, Chinsurah, Amta, Arambagh, Sainthia, Rampurhat, Bongaon, Bagnan, Lohardaga, Jhumritilaiya, Chas, Khatra, Jangipur, Tarakeswar, Sonamukhi, Santipur, Jhargram, Ghatal, Tamluk, Raniganj, Kandi, Lalbagh, Sindri, Kodarma, Rajmahal, Naihati, Bansberia.

A COMPARATIVE APPROACH TO THE MERITS/DEMERITS OF FOUR MODELS AND DERIVATION OF URBANISATION QUANTUM :

1. In all the four models it is found that till the fourth order the central places are expected to be urban places. Even in the 5th order some of the centres will represent urban places for marketing, transport and composite principles.

2. Generally, district centres and cities and class-II towns when taken as second and third order centres there appears a misfit in view of their central place population. Usually higher and higher are the values of K, size of central places in the cases of first three models are more and more satisfactory. Sizes of central places are always logical when ranges of population are given as may be the case of last model.

3. The farthest distance travelled would be accepted depending on the existing modes of transport available,

density of motorable/metalled/unmetalled roads, density of railway tracks, accessibility etc., particularly for higher order centres. In case of lower order centres the distance to be allowed depends on limitations of walking. Limitation of walking distance is a factor of the function to be diffused. If the purpose of visit is for purchasing wholesale goods, the distance to be walked down would be permitted more than that for school facilities. Distance also increases/decreases with the functions of higher/lower order.

For all the four hierarchical patterns distances required to be travelled for the first three orders are acceptable, though not so much satisfactorily in the western districts of the Basin as in the eastern ones due to some physiographic constraints and less developed transportation systems. The fourth order travelling distances are quite acceptable for all the models when short-trip bus journeys or cycle trips are considered. However, the distance to be travelled for a fifth order centre from the farthest point has become as high as 8.3 miles in marketing principle (model-II) as compared to 2.8 miles in administrative principle (model-I). The later one could be walked down for obtaining fifth order facilities while it cannot be thought of in the former case. Model-III also provides quite a long walking distance (5.3 miles) for fifth order facilities. In the same way the variations of calculated distance from one model to another at different levels pose problems while choosing comparative advantages of these models.

4. Accepting the average population of central places at different levels and taking actual individual projected population of centres of the last model an overall picture of urbanisation could be traced out. The Table-11 shows urban populations at different orders of centres, which when totalled provides level of urbanisation according to different models. The projected urban population of the Basin as estimated by the growth rate of 1951-61 period would be about 169.53 lakhs. This means that by 1981, the Basin is expected to experience a level of urbanisation of the order of 29.5 per cent. The four models assess different levels of urbanisation by 1981, the highest of which is 23.6 per cent in the case of model-IV giving nearest figure to the projected urbanisation level. The lowest figure of 13.2 per cent is recorded for model-III, while 18.5 per cent remains as second closest figure (less by 11.0 per cent) to the projected urban population.

In any case, none of the models could provide such a high but acceptable level of urbanisation as estimated by actual projection. However, it seems that not less than 25 to 30 per cent of the total population of the Basin would be required to live in urban places in 1981. This difference of 7 to 10 per cent urban population (over model IV or III) would be explained by the need of intensive central place functions at different orders of centres for the fastest development of the regional economy as well as by the rapid development of large and medium scale industries specially engineering, mineral based and chemical types which would help increased generation of income by processing of goods within the region itself. A portion of the

TABLE—11

Urbanisation Pattern derived out of four Models for 1981

	Models			
Order	I	II	III	IV
1st	11.20	26.67	26.36	45.00
2nd	17.71	21.29	20.56	22.50
3rd	29.78	15.67	14.52	23.40
4th	47.60	13 56	10.62	28.20
5th	Rural	8.45	3.34	16.20
Total Urban Population	106.31	85.64	75.40	135.30
Percentage Urbanisation	18.5	15.0	13.2	23.6

increased urbanisation may also be explained by the need of gainful employment of the persons who are now in disguise in the primary sectors and so encompassed in the rural component.

REFERENCES

Baskin, C. W. (1957) : *A Critique and Translation of Walter Christaller's Die Zentralen Orte in Süddeutschland,* Doctoral dissertation, University of Virginia.

Bell, Friderick W. (1967) : *An Economic Forecasting Model for a Region,* Journal of Regional Science Vol. 7, No. 2.

Berry, Brain J. L. (1967) : *Policy Implication of an Urban Location Model for the Kanpur Region*—Paper submitted at the Seminar on Urban Industrial Growth of the Kanpur Region—January-February, 1967.

Census of India, 1961 : (a) *West Bengal* (b) *Bihar.*

C.M.P.O., *Regional Planning for West Bengal,* Calcutta.

Czamanski, S., (1965) : *A method of forecasting Metropolitan growth by Means of Distributed lag Analysis,* Journal of Regional Science, Vol. 6.

Pathak, C. R. & Chattopadbyay, R. N. (1968) : *Future Metropolises of India*—Paper submitted at Joint Symposium on Metropolitan Growth and Development, I G.U. 1968.

Thomasse H. (1957) : *A Growth Model for a State,* Southern Economic Journal, 24, 1957.

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